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CHEMISTRY FOR BEGINNERS AND SCHOOL USE

KINGZETT

THIRD EDITION

BAILLIÈRE, TINDALL & COX

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CHEMISTRY FOR BEGINNERS
AND SCHOOL USE

PRINTED IN GREAT BRITAIN

CHEMISTRY FOR BEGINNERS

AND SCHOOL USE

BY

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ETC., ETC.

THIRD EDITION (*REPRINTED*)

LONDON
BAILLIÈRE, TINDALL AND COX
8, HENRIETTA STREET, COVENT GARDEN
1919

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"The world is God's Epistle to mankind."
PLATO.

PREFACE TO THIRD EDITION

ORIGINALLY this book was planned to give a sound basic understanding and knowledge of Chemical Science to school boys and girls and other beginners having no opportunities of witnessing or making practical experiments, but it was written in such a way that teachers could give laboratory demonstrations and make experiments for pupils to witness where facilities existed. I have now added a new part (V.), which can be used by teachers and students alike for making practical acquaintance with the subject.

It is a very curious thing to note that in most, if not all, other elementary works, as also generally in the practical teaching of chemistry, students are left to make themselves acquainted with the apparatus and appliances which it is necessary for them to employ, quite casually, as best they can, in course of making experiments, but I think this is wrong, and that they should first of all acquire information respecting the equipment of the laboratory before proceeding to use the implements required for experimental work.

The new part of this book is illustrated with eighty-one figures of apparatus and appliances ordinarily employed in chemical laboratories, and plain directions are given how to make experiments illustrative, at one and the same time, of their character and uses, as also the subject-matter of the whole book. Thirteen are from original drawings; for fifty of the others I am gratefully indebted to Messrs. John J. Griffin and Sons, of Kemble Street, Kingsway, W.C., and for the remaining eighteen to Messrs. Baird and Tatlock (London), Ltd., of 14 and 15, Cross Street, Hatton Garden, E.C.

C. T. KINGZETT.

FRINTON-ON-SEA.
June, 1918.

PREFACE TO SECOND EDITION

THE first issue of this little book was received with so much favour and so quickly exhausted that the Author has had no hesitation in preparing a second edition. Some rearrangement of matter has been made, and it has been carefully revised and considerably enlarged by the incorporation of some additional information.

The commercial welfare of the British Empire depends upon production, and that in turn is dependent upon the utilization of natural resources by the application of chemical knowledge. This small book provides a good groundwork of chemistry as dealt with from a practical standpoint, and is not beyond the capacity of boys and girls of fourteen years of age and upwards, although it may be usefully employed by older persons who desire to acquire a good general knowledge of the subject.

By conveying, as far as opportunity may admit, the information afforded in the following pages to their pupils, school-teachers generally can render material assistance towards that reconstruction of the Empire's affairs which is now the subject of so much consideration.

The Author, who commenced his chemical education at the age of thirteen, is not without practical experience as a teacher, and is satisfied that the bulk of the information can be readily assimilated by pupils under good teachers sufficiently acquainted with the subject-matter and with the aid of blackboard illustrations.

The subject-matter is so arranged that teachers may select and omit sections as may be deemed expedient, and deal with them generally in such order as may be thought best adapted to the age and capacity of the pupils.

The Author desires to express appreciation of the kindness of his friend Mr. R. C. Woodcock, F.I.C., for assistance received in revising the proof-sheets.

C. T. K.

"MAPLIN,"
FRINTON-ON-SEA.
November, 1917.

PREFACE TO FIRST EDITION

THE phenomenal industrial progress made by Germany during the last half-century has, in the main, resulted from the wide teaching and application of chemical science in that country, and it is only by the general spread of scientific knowledge and its applications to the arts and industries that our Empire can hope to regain that superior position which it was so rapidly losing to Germany before the War.

Being profoundly convinced that the future commercial prosperity of the British Empire chiefly depends upon the greater cultivation of science and, in particular, the utilization of chemical knowledge in respect of its natural resources, I am anxious that we should commence at the beginning and in future give *all* our boys the earliest opportunity of acquiring an elemental knowledge of such subjects. While the children of the poorer classes are not afforded the opportunity of gaining this knowledge, they have no chance of competing with those more privileged, and there is, in consequence, a corresponding loss of brain power to the nation. I therefore hope that this little book, or some other one better designed for the purpose, may be used for educational purposes in all the primary and public schools of the Empire and find many students among the public at large.

The information which is given herein will qualify those who may acquire it, to readily progress to a fuller knowledge of these subjects, and that in turn may be had at our secondary schools, colleges and other educational institutions, as also by the study of more advanced books.

Whatever may be the paths in life or business pursuits which boys of all classes may be called upon to lead after leaving school, this simple knowledge will be found most useful. In mechanics, engineering, trades and professions of all sorts, and, indeed, in every walk in life, an elementary knowledge of chemistry and physics will prove both advantageous and profitable.

Much or all of the information afforded in the following pages can be conveyed to pupils by using the several sections as mere reading matter when there are no facilities for giving laboratory demonstrations or making illustrative chemical experiments for the pupils to witness.

In conclusion, I desire to gratefully acknowledge the kind help received from my friends Mr. R. C. Woodcock, F.I.C., and Mr. H. F. Bottomley, F.C.S., in seeing the following pages through the press.

THE AUTHOR.

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CHEMISTRY FOR BEGINNERS

PART I

MATTER.

THE world and all things that are in it and on it are made up of so-called *matter*. Rocks, minerals, vegetables, animals and all living and dead things, are composed of matter, and, as we shall presently see, there are many kinds of matter, some of which are called elements, whilst others are either mixtures or compounds (combinations) of two or more elements.

For example, gold is an element, and no matter what is done with it or to it, nothing can be got from it but gold. The metal lead is another element, and nothing but lead can be obtained from it. In other words, an element as understood by chemists means a substance which is incapable of undergoing any change of nature; that is to say, it cannot be analyzed or decomposed or split up into two or more distinct substances.

In recent years several substances which had up to that time been regarded as elemental have been resolved into products differing from the originals, thus proving that after all they were not elements, and it may well be that means may yet be found by which others or all of them may be decomposed into more simple principles. There are some who hold the view that the substances at present classified as elements are not really ultimate and absolutely distinct, but are compounded of one and the same primordial matter (protyle), and only differ in properties according to the varying conditions under which they are revealed to us and recognized as so-called elements. However that may be, the science of chemistry must be studied in the meantime as if these elements are quite real.

By way of further examples, the metals known as iron, tin, and copper, are elements, and as an instance of compounds, mention may be made of common rust, which forms on iron when exposed to damp air, and which is a compound of iron and oxygen—a gas which is contained in the air—and known as oxide of iron.

Common sulphur is an element of another class, and when it is burned it combines with the oxygen of the air, forming a strong-smelling gas which chemists call sulphur dioxide. Common salt (table salt) is a chemical compound of the two elements sodium and chlorine. Ordinary drinking soda-water, as supplied in siphons, is water charged under pressure with what is popularly known as carbonic acid gas and affords an instance of a mixture as distinct from a chemical compound (see page 7). Water can also be similarly charged with air or oxygen gas; on releasing the pressure, the water and the gas escape together, but the gas that causes the effervescence was not previously in combination with the water, but only held in solution (see page 5) or dissolved therein.

Coal-gas as used for lighting purposes, is really a mixture of several distinct gases, and upon burning, it also enters into combination with the oxygen of the air and forms a number of products, including water and so-called carbonic acid gas (carbon dioxide).

Matter is indestructible—its form only can change, not its nature or essence—and chemistry is sometimes described as "the study of the laws of changes of matter."

It is to be noted that when elements enter into combination they lose their individual properties or characteristics.

States of Matter.

There are three well-known *states* of matter familiar to all—namely, the fluid, solid and gaseous states. For example, quicksilver or mercury (as it is called in chemistry), is, as ordinarily known, a liquid metal, but if it be heated sufficiently in a closed vessel it passes into the state of gas or vapour, and may be distilled (see Distillation) just in the same way as water can be. On the other hand, if it be cooled sufficiently (frozen), it becomes a hard metallic solid.

Again, water is a fluid, but when boiled it becomes steam or vapour, which is a form of gas, and when frozen it becomes ice or solid water.

Properties of Substances.

Besides the differences in the forms, weights, and colour of substances, they vary in their other properties. For example, glass, flint, and iron, are hard, whereas butter and cheese are soft in character.

Some substances are transparent in character, whilst others are opaque. Others, such as spirits of wine (alcohol), chloroform and ether, are termed *volatile* in character; that is because upon gentle heating, and more slowly even at the ordinary temperature of the atmosphere, they pass away into the state of vapour, or volatilize—that is, they pass from the liquid into the gaseous state.

Some chemical substances are said to be *crystalline* in character; that is to say, they can be obtained in geometrical or symmetrical forms, as, for example, common washing soda, common salt, and the crystals of gypsum (sulphate of calcium), which are often found in beds of clay.

Others are described either as *colloids* (see Colloid, also page 29) or *amorphous* in character—that is, devoid of geometrical form.

Again, other substances, such as india-rubber, are said to be elastic—that is, capable of being stretched and recovering their original form more or less when released—whereas most others are practically inelastic. Some are cohesive or sticky in nature; others are granular or particulate; they vary greatly in taste and odour, and while many are harmless, others are more or less poisonous.

Some of the metals are harder than others; for instance, iron is harder than lead, and cannot, therefore, be bent so easily or so easily scraped, say with a penknife.

Some crystalline substances, when exposed to the air, combine with the moisture contained therein, and pass into other crystalline forms which contain more water in their composition, and in some cases this combination with more water goes on until the substance liquefies. Such substances are described as *deliquescent*. For example, when common salt is exposed to the air (which always contains moisture) it becomes damp and cakes, because it has what is called an attraction or affinity for moisture, which it soaks up (absorbs) from the air. Quicklime also has an affinity for atmospheric moisture, and gradually becomes what is called *slaked lime*, although the product is not deliquescent in character.

On the other hand, there are other chemical crystalline substances containing water in their composition which just as readily give it up when exposed to the air, and lose at the same time their geometrical form. For instance, common washing soda, which is a crystalline carbonate of sodium, gradually loses a great part of its water, as also its particular geometrical form, and becomes reduced to a powder, the particles of which have a different geometrical form. In other words, the washing-soda crystals are said to *effloresce*. (See Efflorescence.)

Substances vary also in many other respects. For example, wood and paper are combustible (easily burned), whereas iron and tin do not burn when heated. When a match is struck, the preparation with which it is tipped becomes hot by friction, and, combining with the oxygen of the air, bursts into flame and sets fire to the wooden stick.

Porosity is another character, meaning possession of pores or cavities (looseness of binding). For example, pumice-stone and charcoal are porous as compared with, say, iron or steel, which cannot be pierced in this way. Many porous things (notably sponge) are absorbent, and can in consequence take up or hold in a mechanical sense large quantities of water or other liquids, and they can be squeezed by pressure into smaller compass, the liquid being then forced out.

Solution

If a spoonful of salt be placed in a cup of water and stirred, the salt will gradually disappear. The salt is *dissolved* by the water, and the water, which was previously tasteless, becomes saline in taste and what is called a *solution* of salt. Many other liquids have this power of dissolving solid substances. For instance, solid camphor is easily dissolved by spirits of wine (alcohol), and rosin can be dissolved in turpentine.

When sugar is placed in a cup of hot water or tea or coffee, it dissolves and makes the liquid sweet in character, and the mixture becomes in the same sense a solution of sugar.

There is good reason for believing that when some substances are dissolved in liquids, real chemical combination takes place, as, for example, when carbonate of sodium is dissolved in water; for if this solution be concentrated by evaporation to a sufficient extent, there is produced on cooling, a mass of crystals of common washing soda in which the carbonate of sodium is definitely combined with water ($Na_2CO_3, 10H_2O$). These crystals melt when gently heated, and are decomposed, giving off water in the form of steam and leaving a white powder consisting of the original carbonate of sodium in the *anhydrous* state—that is, devoid of water as a constituent.

As a general rule, the solubility of a solid in a liquid increases with the temperature, and when a solution will not dissolve any more of the solid substance at any particular temperature it is said to be *saturated*.

A solution is said to be dilute in character when it contains but little of its particular ingredient, and is described as strong or concentrated when the proportion of dissolved substance is great in quantity.

Many solutions which are not already saturated can be strengthened or concentrated, as chemists term it, by evaporating off some of the solvent. For instance, a solution of common salt in water may be concentrated by the application of heat, which causes the evaporation or passing off in the state of vapour of some of the excess water. Similarly, a solution of rosin in turpentine can be concentrated by heating, which causes the evaporation or volatilization of some of the solvent turpentine.

On the other hand, strong solutions can be weakened or, to use the chemical description, *diluted* by the addition of more solvent; for example, a syrupy solution of sugar in water can be thinned or diluted by the addition of more water.

In the solid state, substances have not the property of mixing with each other in the sense that liquids and gases have. Of course, they can be mixed together by hand or machinery, but even then only imperfectly, whereas liquids may in many cases be mixed together in a much more complete sense. In fact, they are *miscible* with or soluble in one another. For instance, vinegar and water placed together in a bottle and shaken, gives a mixture of dilute vinegar of which every drop is identical with every other drop. Other liquids, however, will not mix together—for example, oil and water—but *all* gases will mix together. Oxygen and nitrogen, for example, as they exist in the air are thoroughly admixed, and every part of the air is identical in composition with every other part. That is to say, the proportions of their constituents, oxygen and nitrogen, are uniform. Gases have the property of mixing with, or diffusing into each other even more than liquids, while solids have to be forcibly mixed together to effect a mixture, and even then such a mixture is never an absolutely perfect one; it is only at best what may be called an imperfect "mechanical" mixture. Some solids, such as the metals tin and lead, melt or fuse upon being heated sufficiently, and in this molten or fused state some of them can be mixed together, as we shall see when we come to describe what are called *alloys*. Similarly, fats melt on the application of heat, and when melted they can be mixed together (admixed).

Mixtures and Compounds.

There is a great difference between a mere mixture and a chemical compound.

If some common lead shots be mixed with some powdered sulphur ever so carefully, they can be easily separated again. For instance, the sulphur can be blown away from the mixture by a bellows, or all the shots can be picked out or removed one by one. But if, instead of removing the shots, the mixture is subjected to strong heat, both the lead and the sulphur disappear as such. They enter into combination with each other in a chemical sense, and a new substance or chemical *compound* is formed, named sulphide of lead, which has properties or qualities quite different from those of the lead and the sulphur from which it is produced. Again, the formation of rust on iron articles is an example of a chemical combination of the metallic iron and oxygen (as contained in the air). The tarnish which forms on articles of silver when exposed to the air of towns is also a chemical combination of silver and sulphur, or so-called silver sulphide, due to the presence of traces of a compound of sulphur in the air.

Iron filings may be mixed ever so carefully with sand; but this, again, is a mere mixture, and all the iron filings may be separated or withdrawn from the mixture by means of a magnet, which attracts the iron and not the sand, showing that they are not in chemical combination, but only admixed.

Gunpowder is only a mechanical admixture of nitre, charcoal, and sulphur, and their separate respective particles can be seen lying apart from each other by means of the microscope. (See Explosives.)

As a further instance of the difference between a mere mixture and a chemical compound it may be mentioned that when quicksilver (mercury) is strongly heated and exposed to the air, it becomes changed into a yellow powder (an oxide of mercury) which is a chemical compound of the mercury and atmospheric oxygen, and by no mere mechanical process can the mercury and the oxygen of which it is compounded or formed be separated from each other, showing that it is not a mere mixture of the two things.

Decomposition.

A chemical compound can, however, be broken up into its constituent parts by chemical or physical means, and when so separated the compound is said to be decomposed. Decomposition is the breaking up of a compound into its parts by means of a greater force than that of the chemical affinity which binds them together.

There are many ways or methods of effecting the decomposition of chemical compounds. As we have seen, some can be readily decomposed by heating; in others an electric current passed into their solutions will effect the purpose, whilst in yet other cases mere exposure to light suffices, many of the silver compounds, for example, suffering chemical change in this way; and practical advantage of this fact is taken in the art of photography.

Water consists of a combination of two gases, named hydrogen and oxygen, and it can be decomposed or broken up into them again by passing a current of electricity into it.

Limestone, of which the common limestone rock is chiefly composed, is a chemical combination of lime and carbonic acid gas (carbon dioxide), and when it is strongly heated—as is done practically in lime-kilns—it is broken up or decomposed into the two parts. The lime which is left in the kiln is itself a chemical compound of a more simple nature, consisting as it does of the metal calcium and the gas oxygen, whilst the carbonic acid gas which escapes from the kiln is also a chemical compound of an element named carbon (which forms the chief constituent of charcoal and the precious stones known as diamonds) with oxygen (which, it will be remembered, is one of the gases found in the atmosphere or air).

Common rust, which forms upon iron when exposed to damp air, can be broken up or decomposed into iron and oxygen, of which we have shown it to be formed. Similarly, lead sulphide can be broken up or decomposed into the sulphur and the lead of which we have shown it to be formed (compounded).

Again, the yellow oxide of mercury which is formed as explained above (under the heading of Mixtures and Compounds) can be broken up or decomposed into its two constituents (parts) by exposing it to a greater heat than that which is necessary to produce it from the mercury and oxygen of which it is composed.

Chemical Changes and Synthesis.

Compounds can not only be split up (decomposed) into the parts of which they are made, but these parts can also be made to combine together again to form compounds, and this act is known by the term *synthesis*. For example, as previously pointed out, if the metal mercury be heated in a small dish in presence of air, it slowly combines with the oxygen of the air, and is converted into a yellow powder of oxide of mercury. That is an act of chemical synthesis, which is the reverse of *analysis*.

The production of rust upon iron exposed to damp air is also an act of synthesis, the oxygen of the air entering into combination with the metallic iron and forming an oxide of iron. Similarly, when metallic copper is exposed to the action of damp air it gradually turns green in colour and becomes coated with a substance called verdigris, which is a combination of the copper with the oxygen and other substances present in the air. (See Verdigris.)

Again, the gas hydrogen is inflammable—that is to say, it will take fire if a lighted match be applied to it; so that if a small jet of the gas, as issuing from a holder or container, be lighted and allowed to burn in the air, it combines with the oxygen of the air and forms water synthetically.

Chemical attraction or affinity—the force, that is to say, which brings about such combinations as have been instanced—must be regarded as identical in essence with the other forms of force known to us, such as light, heat, electricity, magnetism and gravitation; indeed, all chemical changes involve the exhibition of force in some form or other, many being attended, as we shall presently see, with the production of light and heat.

All things that we eat and drink, both natural and manufactured; the clothes we wear; the materials of which our houses and buildings are constructed, as also those used in their repair and decoration; every art, every industry (including the munitions of war), all depend essentially upon chemical changes as realized in nature, or made by man to serve the purposes of civilization. Again, the decay of animal and vegetable matters, and the changes by which these are broken up into other substances available in their turn as food for new life; the very diseases to which mankind and animals are subject, and their treatment, are all chemical in essence.

Atoms and Molecules; Atomic Weights and Combining Proportions.

By the word *atom* chemists mean the smallest particle of any element that can exist in a state of combination, or that can take part in a chemical change. Atoms are supposed to be indivisible, although there are no means of ascertaining the real size of the ultimate particles or atoms of matter. It is further supposed that all the atoms of any one element are of the same size and weight, but that they differ from those of all the other elements in mass (weight) and chemical properties.

Chemical combination always takes place in equivalent proportions or relative (atomic) weights of these atoms.

Molecule means the smallest quantity of any substance which is capable of existing in the free state or separate form. For instance, the molecule of common salt consists of one atom of the metal sodium with one atom of the gas chlorine. Molecules of the elements and their weights are further dealt with in another part of the book (see page 21).

There are probably no such things as atoms in reality, because everything, no matter how small, can be again divided into two or more parts. They are to be regarded as the smallest particles that can enter into or be expelled from any chemical compound, or take part in any chemical change, and the so-called atomic weights really represent the relative weights in which the elements displace each other in chemical changes, that of hydrogen (the lightest of them) being generally taken as unity.

Of all the chemical elements (see pages 13 and 113), hydrogen is the lightest, and platinum and lead are two of the heavier class. Air is nearly 14½ (14·4) times as heavy as hydrogen. Oxygen (one of the constituents of the air) is 16 times heavier than hydrogen, and nitrogen (the other chief constituent of air) is 14 times heavier than hydrogen. These weights are termed their *atomic weights* or combining proportions.

The table on page 13 gives not only the names of the better-known elements, but also their so-called symbols and their atomic weights as generally used.

When the elements combine together—as, for example, hydrogen and oxygen to form water—they combine in proportions of their atomic weights, or multiples of them; in this case 2 pounds of hydrogen combine with 16 pounds of oxygen, and form a quantity of water weighing 18 pounds.

Lead has an atomic weight of about 207, so that when (as noted on page 7) it enters into chemical combination with sulphur, which has an atomic weight of 32, 207 parts by weight of lead combine with 32 parts by weight of sulphur, and yield 239 parts of the chemical compound sulphide of lead.

By way of further example, common salt (sodium chloride) is a chemical combination of 23 parts by weight of the metal sodium and 35½ parts by weight of the gas chlorine, or, in other words, a combination of one atom of each of these two elements. The two atoms thus combined make up a *molecule*, so that the molecular weight of the compound (salt) is that of the two added together—namely, 58½. When salt is decomposed—that is, split up by chemical means into its two constituent elements—58½ parts by weight always yield 23 parts by weight of sodium and 35½ parts by weight of chlorine.

Chemistry deals with known quantities, and no chemical study is complete until the sum of the products of any chemical change is found upon examination to equal in weight that of the substances originally employed.

The exact number of elements in nature is not known with certainty. Eighty-three or more are known, but there may be more yet undiscovered; but, at the same time, it is quite possible that, as already pointed out, some of the so-called elements are not really elements at all, but compounds.

Most of the elements are metals, but the non-metallic ones exist more abundantly in nature, and include oxygen, silicon, hydrogen, nitrogen, carbon, chlorine, bromine, and iodine.

In the table given opposite, the metallic elements are marked with a +, while those marked *G* exist ordinarily in the gaseous form. These elements and some of their compounds are described in the following pages (Part III.), and references to some of the rarer elements not included in this list will also be found in the text.

Better Known Elements.

LIST, WITH THEIR SYMBOLS AND ATOMIC WEIGHTS, HYDROGEN (1) BEING TAKEN AS THE STANDARD.

Name.	Symbol.	Atomic or Combining Weight.	Name.	Symbol.	Atomic or Combining Weight.
+ Aluminium	Al	27	+ Magnesium	Mg	24
+ Antimony	Sb	120	+ Manganese	Mn	55
+ Arsenic	As	75	+ Mercury	Hg	200·6
+ Barium	Ba	137	+ Nickel	Ni	59
+ Bismuth	Bi	208	*G* Nitrogen	N	14
Boron	B	11	*G* Oxygen	O	16
Bromine	Br	80	Phosphorus	P	31
+ Cadmium	Cd	112	+ Platinum	Pt	195
+ Calcium	Ca	40	+ Potassium	K	39
Carbon	C	12	+ Radium	Ra	226
G Chlorine	Cl	35·5	Silicon	Si	28
+ Chromium	Cr	52	+ Silver	Ag	108
+ Cobalt	Co	59	+ Sodium	Na	23
+ Copper	Cu	63·5	+ Strontium	Sr	87·6
G Fluorine	Fl	19	Sulphur	S	32
+ Gold	Au	197	+ Thorium	Th	232
G Hydrogen	H	1	+ Tin	Sn	118
Iodine	I	127	+ Uranium	U	238
+ Iron	Fe	56	+ Vanadium	V	51
+ Lead	Pb	207	+ Zinc	Zn	65
+ Lithium	Li	7			

Symbols and Formulæ.

The symbol of hydrogen is H, that of nitrogen N, that of oxygen O, and it will be seen from the foregoing table that most of the elements have symbols consisting of their initial letter or that followed by a second letter only; but there are exceptions, and it will be useful to explain the reason.

The metal antimony has the symbol Sb because the Latin name for antimony is *stibium.*

The metal lead has the symbol Pb because the Latin name for lead is *plumbum.*

The metal mercury is indicated by the letters Hg, as the Latin name for it is *hydrargyrum.*

Potassium is symbolized by the letter K because its Latin name is *kalium.*

Sodium is symbolized by Na because *natrium* is its Latin name.

The metal tin has the symbol Sn, from the Latin name *stannum.*

The metal gold is marked Au, from the Latin name *aurum.*

The metal iron is marked Fe, from the Latin name *ferrum.*

The metal silver is marked Ag, from the Latin name *argentum.*

The metal copper is marked Cu, from the Latin name *cuprum.*

It is a pity that the symbols of these exceptional instances are still used, but while they are used it is well to know their derivation.

The constitution of compounds is represented by so-called *formulæ* or combinations of letters or symbols; thus, the formula of common salt (chloride of sodium) is $NaCl$, that of water H_2O, and so forth.

Classification of the Elements.

The chief elements can, to some extent at least, be classified into natural groups in respect of their resemblances—viz., as follows:

1. *Alkali metals*, including potassium, sodium, lithium.

2. So-called *alkaline-earth* metals, including barium, strontium, calcium, and magnesium.

3. *Halogens*, including chlorine, bromine, iodine, and fluorine.

4. A larger group may be defined as more definitely metallic than those referred to in classes 1 and 2, and include aluminium, antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, gold, iron, lead, magnesium,

manganese, mercury, nickel, platinum, silver, tin, vanadium, and zinc.

5. Those which are better known in their gaseous state are—hydrogen, chlorine, fluorine, oxygen, and nitrogen.

6. The non-metals include all the elements in classes 3 and 5, also iodine, sulphur, bromine, carbon, phosphorus, and silicon.

Carbon is peculiar as being the one essential element of all so-called organic compounds, whilst silicon is one of the most abundant elements found in nature. Apart from carbonates of the metals, most of the other compounds of carbon are known as *organic* compounds, and, indeed, organic chemistry is sometimes defined as the chemistry of carbon and its compounds. These compounds are more numerous than those of all the other elements, and so far as they are constituents of animal and vegetable tissues, they are of more complicated constitution than most other chemical compounds: besides oxygen and hydrogen, they not infrequently include nitrogen, sulphur, and phosphorus as constituents.

Chemical Interactions (Reactions) and Equations.

If some zinc filings be placed in a dilute solution of hydrochloric acid, a chemical change or *interaction* is seen to take place, the metal being gradually dissolved, and an effervescence ensues which is due to the formation of hydrogen gas, whilst a solution of zinc chloride is produced as the result of the change.

Using the symbols which have already been explained, chemists represent this chemical change as follows:

$$\begin{aligned}&\mathrm{Zn}\ \text{(zinc)} + 2\mathrm{HCl}\ \text{(hydrochloric acid)}\\ &= \mathrm{ZnCl_2}\ \text{(zinc chloride)} + \mathrm{H_2}.\end{aligned}$$

That is to say, 1 atom of zinc and 2 molecules of hydrochloric acid give rise by interaction to 1 molecule of zinc chloride (which passes into solution) and 2 atoms of hydrogen which escapes as gas and causes the bubbling or effervescence.

Similarly, if some broken pieces of marble (which consists of carbonate of calcium) be placed in a dilute solution of hydrochloric acid, they dissolve therein, with effervescence, due to the escape of carbon dioxide (carbonic acid) gas, which results, in consequence of the chemical change that takes place between the marble and the acid. This change is expressed as follows:

$CaCO_3$ (carbonate of calcium, or marble) + 2 HCl (hydrochloric acid) = $CaCl_2$ (chloride of calcium) + H_2O (water) + CO_2 (carbon dioxide). In other words, 1 molecule of calcium carbonate and 2 molecules of hydrochloric acid (or hydrogen chloride) produce 1 molecule of chloride of calcium (which passes into solution), 1 molecule of water, and 1 molecule of carbon dioxide.

Again, a bright sheet of lead, if rubbed over with powdered sulphur, will gradually blacken, and this is caused by the two elements interacting or undergoing a chemical change, which produces sulphide of lead on the surface of the metal. The result of this change may be represented by symbols as follows:

$$\text{Pb (lead)} + \text{S (sulphur)} = \text{PbS (lead sulphide)}.$$

That is to say, the lead and the sulphur combine in proportions of their atomic weights; 1 atom or 207 parts by weight of lead combine with 1 atom or 32 parts by weight of sulphur, and produce a molecule or 239 parts of lead sulphide (PbS). Take another instance.

The elemental substance called phosphorus (which, in one of its forms, is extensively used in making the composition used for coating the surface of match-boxes) has a great affinity for—that is, a liking or tendency to enter into chemical combination with—oxygen, which, it will be remembered, is one of the constituents of the air we breathe. Well, if a piece of phosphorus be sufficiently warmed (heated to 34° C.) or ignited, and then placed in a glass jar filled with oxygen gas, it combines with it at once, bursts into vivid flame, and after cooling, it is found that on the bottom and sides of the glass jar there is a white deposit resembling snow.

First of all to explain the flame. This is caused by the heat which results from the affinity or greed of the phosphorus to enter into chemical action with the oxygen, and the white deposit is the product or result of the chemical action, being what is called an oxide of phosphorus having the formula P_2O_5. This means that 2 atoms of P weighing twice 31 =62 (31 being the atomic weight of P) combine with 5 atoms of oxygen, weighing in all 80 (16 being the atomic weight of oxygen), and make 142 parts by weight of the resulting product. Now, as air consists of a mixture of oxygen and nitrogen, if enough phosphorus be employed to use up all the oxygen that is present, only nitrogen is left behind in the gaseous state, and that is one method of preparing nitrogen. Supposing exactly 100 parts of air be used in this experiment, 21 parts of the air, consisting of oxygen, enter into chemical combination with the phosphorus, and 79 parts of the air, consisting of nitrogen, are left behind.

Heat is often given out as the result of chemical interchanges, but not always; sometimes the reverse is experienced, and cold is, so to speak, produced.

Let us now take another instance representing what takes place chemically when a piece of charcoal or coke is burnt in an ordinary fire-grate or flame. The charcoal or coke may be said to consist, in the main, of the element carbon, and when this is burned in the air, the carbon enters into chemical combination with the oxygen present therein, and produces what is popularly called carbonic acid gas, but better defined as carbon dioxide. This is represented by symbols in the following *equation :*

$$C+O_2=CO_2.$$

Each atom of carbon chemically combines with 2 atoms of oxygen, and gives rise to the formation (production) of 1 molecule of carbon dioxide gas.

It is to be noted that in this interaction a solid body combines with a gas, whilst the product is entirely gaseous in character, although it can, in point of fact, be converted into the liquid state and even made into a solid form like snow by great cooling under pressure—that is to say, by squeezing (pumping) a great quantity (volume) of the carbon dioxide gas into a very small space whilst cooling or freezing it at the same time.

These instances are so instructive in a general sense that we may well give more of them.

Common washing soda or sodium carbonate is a chemical combination of the metal sodium, carbon dioxide, and water. Well, this metal sodium has a great affinity for the elemental gas known as chlorine, which, by the way, is green in colour. Now, if a small piece of the metal sodium be dropped into a glass bottle full of chlorine gas in a moist condition, a chemical change or interaction takes place between the two substances, and there is produced, as the product or result of that change, a substance which everybody knows well as common salt, or sodium chloride, as chemists name it. Represented by symbols, the change is as follows:

$$\text{Na (sodium)} + \text{Cl (chlorine)} = \text{NaCl}.$$

According to this *equation*, 1 atom each of sodium and chlorine combine together as explained on page 12.

It is to be noted that in this chemical change, sodium, which is a solid metal, combines with a green-coloured gas, and forms a white salt as its product.

Mercuric chloride is a combination of mercury with chlorine, and if a strip of copper be placed in a slightly acid solution of that substance, a change takes place, causing the mercury to be deposited, whilst after sufficient time, nothing but chloride of copper is found in solution. In other words, the mercury is replaced (in consequence of the chemical change that takes place) by the copper, and it is found in practice that this exchange takes place in the proportion of

200·6 parts of mercury and 63½ parts of copper. If this solution of chloride of copper be taken afterwards and exposed, in turn, to the action of a piece of iron, the whole of the copper can be deposited from the solution and replaced by iron; and now it is found that the metals are again exchanged in their equivalent or atomic weights, 63·5 parts copper being replaced by 56 parts iron. These two changes or interactions are expressed by the two following chemical equations:

$HgCl_2$ (mercuric chloride) + Cu (copper) = $CuCl_2$ (cupric chloride) + Hg (mercury).

$CuCl_2$ (cupric chloride) + Fe (iron) = $FeCl_2$ (ferrous chloride) + Cu (copper).

Baryta or barium oxide is represented by the formula BaO, but there is another oxide of barium, which chemists call barium dioxide, which has the formula BaO_2.

Similarly, water, which is an oxide of hydrogen, has the formula H_2O, but there is another oxide of hydrogen which chemists term hydrogen dioxide or peroxide of hydrogen (H_2O_2).

Now, when the substance known to chemists as powdered barium dioxide is added to a solution of dilute hydrochloric acid (which has the constitution represented by the formula HCl), the following change takes place:

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

This chemical equation indicates or represents the fact that 1 molecule of barium dioxide interacting with 2 molecules of hydrochloric acid (hydrogen chloride) produces 1 molecule of barium chloride and 1 molecule of hydrogen dioxide, both of which, being soluble in water, remain together in solution.

It is further evident that the sum of the products is equal to the sum of the substances originally employed, and the equation given above shows that there are employed in this chemical interaction:

1 atom or	137 parts by weight	of barium	As contained in 1 molecule of barium dioxide.
2 atoms or	32 " "	of oxygen	
2 " "	2 " "	of hydrogen	As contained in 2 molecules of hydrochloric acid,
2 " "	71 " "	of chlorine	

totalling 7 atoms and 242 parts by weight;

and that there are produced—

1 atom or	137 parts by weight	of barium	As contained in 1 molecule of barium chloride.
2 atoms or	71 " "	of chlorine	
2 " "	2 " "	of hydrogen	As contained in 1 molecule of hydrogen dioxide,
2 " "	32 " "	of oxygen	

totalling 7 atoms and 242 parts by weight.

Incidentally, this equation also affords an illustration of the indestructibility of matter, the forms and combinations of which only can be changed.

If in the study of any chemical change, the sum of the products found upon analysis is not equal to the parts by weight of the substances employed, it is known to the operator that the analysis is imperfect.

There is another consideration of importance in connection with this study. The formula H_2O_2 not merely implies that 2 parts by weight of hydrogen are combined with 32 parts by weight of oxygen in each molecule of hydrogen dioxide; it also expresses a relation by *volumes* of these chemical elements in combination, for if a molecule of the hydrogen dioxide (in the pure state) be subjected to analysis or decomposition, it yields 2 volumes of hydrogen and 2 volumes of oxygen. On the other hand, water or H_2O yields 2 volumes of hydrogen and only 1 volume of oxygen; but that is because water is a monoxide of hydrogen, whereas H_2O_2 is a dioxide of hydrogen.

As a matter of fact, equal volumes of the different elementary gases—viz., chlorine, fluorine, hydrogen, oxygen, and nitrogen—have the relative or atomic weights given in the table on page 21. To put the matter in another way, 1 gramme* of hydrogen, 16 grammes of oxygen, 14 grammes of nitrogen, $35\frac{1}{2}$ grammes of chlorine, and 19 grammes of fluorine, all occupy the same volume in the gaseous state at the same temperature and pressure.

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* A gramme is a measure of weight equal to 15·43 grains avoirdupois. For other weights and measures see page 33.

The atomic and molecular weights of the elements are derived from a number of considerations which may now be further explained, it being borne in mind that, as given in the table on p. 13, they are all relative to hydrogen, the lightest known element, which is there taken as the unit.

Name of Gas.	*Atomic Symbol.*	*Atomic Weight.*	*Molecular Weight.*	*Molecular Symbol.*	*Vapour Density.*
Hydrogen	H	1	2	H_2	1
Nitrogen	N	14	28	N_2	14
Oxygen	O	16	32	O_2	16
Fluorine	F	19	—	—	19
Sodium	Na	23	23	Na	11·5
Phosphorus	P	31	124	P_4	62
Sulphur	S	32	64	S_2	32
Chlorine	Cl	35·5	71	Cl_2	35·5
Potassium	K	39	39	K	19·5
Zinc	Zn	65	65	Zn	32·5
Arsenic	As	75	300	As_4	150
Bromine	Br	80	160	Br_2	80
Iodine	I	127	254	I_2	127
Mercury	Hg	200	200	Hg	100

It has already been stated (page 11) that an atom is regarded and defined as the smallest portion of any matter that can take part in a chemical change, whilst a molecule is regarded as the smallest part that can exist in the free state.

There is the further assumption now generally accepted by chemists, although it cannot be regarded as proven, that equal volumes of gases at the same temperature and pressure contain the same number of molecules. This assumption, known as Avogadro's law, is taken for granted because it harmonizes with so many known chemical facts. Equal volumes, then, of hydrogen and oxygen, taken by way of example, contain, we will say, each 1 molecule; but as oxygen is known to be 16 times heavier than hydrogen, and the atom of hydrogen having an atomic weight of 1, that of oxygen must be 16, but as the molecule of hydrogen consists of at least 2 atoms, it also follows that its molecular weight as standard must be 2, and that of oxygen therefore 32. In many other cases, as in this one, the molecular weight will be seen to be double the atomic, but this is not always the case; the molecular weight of phosphorus being, for example, 124 or 4 times its atomic weight, and that of arsenic 300, which is also 4 times its atomic weight.

To illustrate this view further, let us take water, which is known to consist of hydrogen and oxygen. As the smallest particle of each of these substances is an atom, the relative weights will be ascertained by finding out the proportions by weight in which they are combined as water, and that is 8 parts of oxygen to 1 of hydrogen, and as 2 atoms of hydrogen make up 1 molecule, its molecular weight is 2, and that of oxygen is consequently 32.

Again, when water is converted into steam or gas, it is found to be 9 times as heavy as an equal volume of hydrogen at the same temperature and pressure, and because equal volumes of gases under these conditions contain equal number of molecules, it necessarily follows that a molecule of water in gaseous form is 9 times as heavy as a molecule of hydrogen gas; and as a molecule of hydrogen consists of 2 atoms, each weighing 1, the molecular weight of water must be 18, made up of oxygen 16 and hydrogen 2 parts by weight.

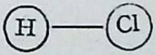
To take another instance, equal volumes of hydrogen gas and hydrochloric acid (HCl) gas, at the same temperature and pressure, weigh respectively 1 and 18¼; but as the weight of hydrogen contained in a molecule of hydrochloric acid is only one-half that of the same element contained in an equal measure or volume of hydrogen, and as there is only 1 atom of hydrogen contained in the molecule of hydrochloric acid, it necessarily follows that the molecule of hydrogen consists of 2 atoms; and, further, taking hydrogen as the unit of weight, the molecule of hydrochloric acid must weigh twice that of the molecule of hydrogen—viz., $2 \times 18\frac{1}{4} = 36\frac{1}{2}$, made up of hydrogen 1 atom weighing 1, and chlorine 1 atom weighing $35\frac{1}{2}$.

As contrasted with the molecular weights of gases, the relative weights of equal volumes at the same temperature and pressure are known as their vapour densities, and it will be seen from the preceding table (p. 21) that these are one-half of the numbers representing their molecular weights.

From these various considerations, it follows that the atomic weights of gases are half the weights of the volumes of them respectively, equal to the volume of a molecule of hydrogen gas at the same temperature and pressure.

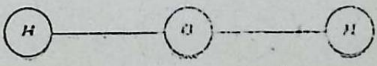
Valency.

The atoms of elements possess a power of combination, or so-called *valency*, more or less peculiar in character. Hydrogen is a so-called monatomic or *uni*valent element—that is, it has only one capability of chemical attachment to another element. Thus, it may be made to combine with chlorine, and the combination may be represented graphically as follows:

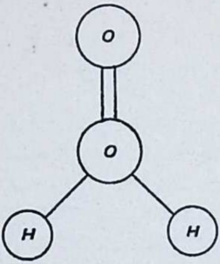


Hydrogen, then, and the other elements which have a similarly restricted valency are called monads.

Oxygen, on the other hand, generally behaves as a *di*valent element and can combine, for example, with 2 atoms of hydrogen or other monovalent element, as shown by the constitutional formula of water, H_2O, which may be graphically expressed thus:

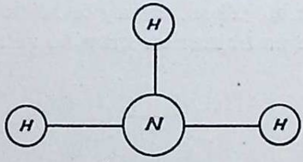


In other combinations, oxygen behaves as a tetrad—as, for example, when it exists in combination with hydrogen as peroxide of hydrogen (hydrogen dioxide) H_2O_2:

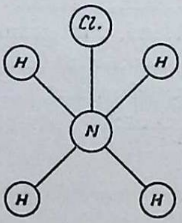


This represents the view that 1 atom of oxygen is attached, on the one hand, directly to the 2 atoms of hydrogen, and (as there is reason for thinking) the other atom of oxygen is itself not in direct attachment or combination with the hydrogen atoms.

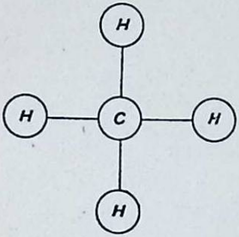
Nitrogen is an example of a *tri*valent element, although in some compounds it behaves as a pentad or *penta*valent. For example, in ammonia (NH_3) it exists in combination with 3 atoms of hydrogen, and may be represented as follows:



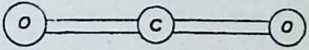
whereas, combined as in chloride of ammonium (NH_4Cl), it would appear to exist in pentavalent combination, thus:



Carbon is an example of the tetrad class—that is to say, it has the power of combining with 4 atoms of hydrogen or 2 atoms of oxygen, as expressed in the two following graphic examples:



(Methane or marsh gas)



(Carbon dioxide)

Acids, Bases and Salts.

Acids.—By the word *acid* is meant, generally speaking, something that is sour. Vinegar, for example, is acid or sour in character and contains what chemists call acetic acid. Acids turn vegetable blue colours into red colours and tincture of litmus—a vegetable dye—is ordinarily employed for such testings.

There are a great number of acids, derived from various sources.

Hydrochloric acid is a combination of 1 part hydrogen with 1 part of chlorine, and is represented by the formula HCl.

Nitric acid is a compound of 1 part hydrogen, 1 part nitrogen and 3 parts oxygen, and is represented by the formula HNO_3.

Sulphuric acid is compounded of 2 parts hydrogen, 1 part sulphur and 4 parts oxygen—H_2SO_4.

These are the three best-known inorganic acids, and they are all largely used in commerce and manufacturing operations.

Citric acid (the acid of citrons and lemons), acetic acid, malic acid (the acid of apples), tartaric acid, and oxalic acid, are five of the better-known acids from organic sources.

These several acids—all of which are soluble in water—by combination with bases form the corresponding chlorides, nitrates, sulphates, citrates, acetates, tartrates, oxalates, etc., as illustrated by the following typical equations:

$$\underset{\text{Hydrochloric Acid)}}{2HCl} + \underset{\text{(Sodium Oxide)}}{Na_2O} = \underset{\text{(Sodium Chloride)}}{2NaCl} + \underset{\text{(Water)}}{H_2O}.$$

$$\underset{\text{(Nitric Acid)}}{HNO_3} + \underset{\text{(Sodium Hydroxide)}}{NaHO} = \underset{\text{(Sodium Nitrate)}}{NaNO_3} + \underset{\text{(Water)}}{H_2O}.$$

$$\underset{\text{(Sulphuric Acid)}}{H_2SO_4} + \underset{\text{(Sodium Carbonate)}}{Na_2CO_3} = \underset{\text{(Sodium Sulphate)}}{Na_2SO_4} + \underset{\text{(Water)}}{H_2O} + \underset{\text{(Carbon Dioxide)}}{CO_2}.$$

These acids and some of their compounds will be described in a later part of the book, and a table giving information as to the solubilities of some of these salts will be found on page 31.

Bases, Alkalies, etc.—are bodies which combine with acids, thereby destroying their acidity, and forming salts. Originally, the compound known as potassium carbonate was obtained from the ashes of seaweed and was called *alkali*, a word of Arabic origin. By the term alkali is now meant something of exactly the opposite nature to acid. The common alkalies are named potash, soda and ammonia.

Potash (or potassium hydrate) is a combination of 1 part potassium, 1 part hydrogen, and 1 part oxygen—KHO.

Potassium carbonate is a combination of 2 parts potassium, 1 part carbon, and 3 parts oxygen—K_2CO_3.

Soda (or sodium hydrate) is a combination of 1 part sodium with 1 part hydrogen and 1 part oxygen—$NaHO$; and sodium carbonate (the essential constituent of common washing-soda) is Na_2CO_3.

Potassium and sodium in combination with oxygen alone form oxides, and their formulæ are as follows: K_2O and Na_2O. It is by combination of these oxides with water that the respective *hydrates* (or, as they are alternatively called, hydroxides) are formed. For example, a molecule of the potassium oxide combining with a molecule of water gives 2 molecules of potassium hydrate, thus:

$$K_2O + H_2O = 2KHO.$$

Ammonium hydrate is a combination of 1 part nitrogen, 5 parts hydrogen, and 1 part oxygen—NH_4HO.

These oxides and hydrates are all soluble in water.

As another instance, let us take barium oxide (BaO), which, when combined with water, forms barium hydrate as follows:

$$BaO + H_2O = BaH_2O_2.$$

In this case, 1 part or molecule of the barium oxide enters into combination with 1 part or molecule of water, and produces 1 part or molecule of barium hydrate, which is also soluble in water. A hydrate is therefore a combination of an oxide and the elements of water.

These alkaline bodies are all more or less soapy to the feel when dissolved in water, and they have the opposite action on colours to acids—they turn vegetable red colours to blue colours.

They are also classified as *bases;* but there are many other kinds of bases, all of which have the property of entering into chemical action with acids to form compounds which are called *salts*.

Salts.—Most of the oxides, hydrates and carbonates of other metals behave as bases, and in common with the alkalies combine with acids to form salts.

When an acid solution is mixed with its equivalent quantity of an alkaline or other basic solution, the acid character of the one solution, and the alkaline or basic character of the other solution, are destroyed or neutralized.

For example, if a solution of sodium hydrate in water be mixed with one of hydrochloric acid, a chemical interaction takes place, and a salt known as sodium chloride (common salt) is produced. This is represented by formulæ or equation as follows:

$$NaHO + HCl = NaCl + H_2O$$

and if the neutral solution which results from this reaction be heated so as to cause evaporation of sufficient of the water, the salt will be obtained, upon cooling of the solution, in a crystalline condition.

When potash is used in place of the soda the change is expressed as follows:

$$KHO + HCl = KCl + H_2O.$$

Lime (oxide of calcium, CaO) is an example of another class of bases, which includes baryta or barium oxide (BaO), magnesia or magnesium oxide (MgO), and strontia or strontium oxide (SrO). When lime is added to hydrochloric, nitric, or sulphuric acid, it enters into combination and forms either calcium chloride, nitrate, or sulphate, as the case may be. Thus, if hydrochloric acid be employed, the change is expressed as follows:

$$CaO + 2HCl = CaCl_2 + H_2O$$

with nitric acid as follows:

$$CaO + 2HNO_3 = Ca(NO_3)_2 + H_2O$$

and with sulphuric acid as follows:

$$CaO + H_2SO_4 = CaSO_4 + H_2O.$$

The chloride and nitrate of calcium are both soluble in water, but the sulphate is almost insoluble.

Crystalline and Amorphous Substances.

Many of the salts above defined are crystalline, and as instances may be mentioned—sulphate of copper, which is soluble in water and crystallizes from its solutions in beautiful blue doubly oblique-rhombic forms; nitrate of sodium, which crystallizes in colourless obtuse rhombohedra; common salt (chloride of sodium), which can be obtained in colourless transparent cubes.

Many mineral substances are found in nature in the crystalline state, some resulting from the cooling of saturated solutions; others, such as the diamond and many other precious stones, probably from processes of fusion resulting from great heat. We know little or nothing of the primary molecular force by reason of which chemical substances can assume such wonderful forms, and this fact alone suffices to indicate that in matters concerning first causes and effects, scientists stand even now but on the very threshold of knowledge.

Substances which can assume crystalline form are known collectively as *crystalloids*, as distinguished from *colloids*, another class of chemical bodies which are not crystalline, and from a large class of so-styled *amorphous* substances, which are also devoid of crystalline form.

The term "colloidal" has a somewhat specific meaning, as distinct from "amorphous." (See Dialysis.)

Oxides, Chlorides, Bromides, Iodides, and Other Compounds.

It has already been stated that combinations or compounds of metals and other bases with oxygen are called oxides, and as further instances, mention may be made of the oxides of zinc, lead, and copper, which are represented by the chemical formulæ ZnO, PbO and CuO respectively.

If in place of oxygen the elements chlorine, bromine, iodine, and sulphur be severally taken and made to combine with metals or other bases, the resulting compounds are chlorides, bromides, iodides, and sulphides.

This is shown in tabulated form as below:

Compounds of—	*Called.*	*Example.*	*Formula.*
Oxygen	Oxides	Zinc oxide	ZnO
Chlorine	Chlorides	Sodium chloride	$NaCl$
Bromine	Bromides	Potassium bromide	KBr
Iodine	Iodides	Potassium iodide	KI
Sulphur	Sulphides	Lead sulphide	PbS

The names used to identify chemical substances are designed as far as possible to indicate their composition, but the system is by no means perfect, and apart from other variations, many old common familiar names are still retained by some chemists and in many books.

It frequently happens that the same two chemical elements combine together in various proportions, so forming as many different compounds, and to distinguish these, terminal letters or prefixes are employed. For instance, the two compounds water and peroxide of hydrogen (H_2O and H_2O_2 respectively), are both composed of hydrogen and water, so the one with the higher proportion of oxygen is styled peroxide or dioxide, water being oxide or monoxide of hydrogen.

Again, phosphorus combines with chlorine to form two chlorides, PCl_3 and PCl_5, and these are termed respectively phosphor*ous* chloride and phosphor*ic* chloride, or preferably, phosphorus *tri*chloride and phosphorus *penta*chloride respectively.

Acids are commonly called by their familiar names, but may be, and often are, described as compounds of hydrogen; for instance:

Hydrochloric acid = Hydrogen chloride.
Nitric acid = Hydrogen nitrate.
Sulphuric acid = Hydrogen sulphate.

The terminals *ic* and *ous* are used to denote acids with the greater or smaller proportion of oxygen, where that element enters into their combinations; thus we get:

Sulphur*ic* acid, formed from sulphur *tri*oxide and water,

$$SO_3 + H_2O = H_2SO_4.$$

Sulphur*ous* acid, formed from sulphur *di*oxide and water,

$$SO_2 + H_2O = H_2SO_3.$$

Nitr*ic* acid, formed from nitrogen *pent*oxide and water,

$$N_2O_5 + H_2O = 2HNO_3.$$

Nitr*ous* acid, formed from nitrogen *tri*oxide and water,

$$N_2O_3 + H_2O = 2HNO_2.$$

When these acids combine with a base—for example, potassium oxide—they form respectively sulph*ate* and sulph*ite* of potassium, and nitr*ate* and nitr*ite* of potassium, or, instead of expressing them as named, they may be described as potassium sulphate, sulphite, nitrate and nitrite respectively.

	Oxides.	*Hydrates.*	*Carbonates.*	*Chlorides.*	*Nitrates.*	*Sulphates.*	*Sulphides.*
Al	I	I	—	S	S	S	I
NH_4	S	S	S	S	S	S	S
Sb	I	I	—	S	—	I	I
As	SS	S	—	S	—	—	I
Ba	S	S	I	S	S	I	I
Ca	SS	SS	I	S	S	SS	SS
Cu {Cupric	I	I	I	S	S	S	I
Cu {Cuprous	I	—	I	I	—	—	I
Fe {Ferric	I	I	—	S	S	S	I
Fe {Ferrous	I	I	I	S	SS	S	I
Pb	I	SS	I	SS	S	I	I
Mg	I	I	I	S	S	S	S
Mn	I	I	I	S	S	S	I
Hg {Murcuric	I	I	I	S	S	S	I
Hg {Mercurous	I	I	I	I	S	S	I
K	S	S	S	S	S	S	S
Ag	I	I	I	I	S	SS	I
Na	S	S	S	S	S	S	S
Sn {Stannic	I	I	I	S	S	S	I
Sn {Stannous	I	I	I	S	S	S	I
Sr	SS	S	I	S	S	I	SS
Zn	I	I	I	S	S	S	I

S=soluble, SS=sparingly soluble, I=insoluble, in water.

The above table shows which of the various compounds of the better-known elements are soluble or insoluble in water. It will be observed that some metals, including copper, iron, mercury, and tin, form two compounds of most of the classes, and these are indicated by the terminations of the metallic names: thus, ferr*ic* chloride is $FeCl_3$, and ferr*ous* chloride is $FeCl_2$; mercur*ic* chloride is $HgCl_2$; and mercur*ous* chloride is Hg_2Cl_2, and so forth. It will be seen that the names of the compounds containing the larger proportion of metal end with the termination *ous;* and those with the smaller proportion, with the ending *ic*.

Metals.—The metallic elements as a class are capable of taking a high polish, but some, of course, more than others. Gold, copper and platinum, for example, may be polished and burnished to a very high degree—much more than iron, lead and arsenic.

Again, some are much more *ductile* than others, and can therefore be easily drawn out into wire. For example, copper in this form is largely used for telegraphic purposes.

Others are of a *malleable* character—that is to say, can be easily beaten into any desired shape with a hammer or mallet—lead, for example. Gold and several other metals can be hammered into extremely thin sheets—gold leaf, for example.

Most metals are good *conductors* of heat and electricity.

There are great differences between the hardness, brittleness, weight, strength and other properties of the various metals.

Alloys.—Many metals when melted together have the property of combining with each other to form either mixtures or compounds called alloys, some of which are very useful in the arts and manufactures. In this way the metals aluminium, zinc, iron, tin, copper and lead are largely used, and sometimes mercury, silver, gold and platinum. So-called *German silver* is a mixture of copper, zinc and nickel; and *brass* consists of about 2 parts copper and 1 part zinc.

Amalgam is the name given to any combination of other metals with mercury. Gold and lead, for example, are somewhat easily dissolved by liquid mercury in varying proportions; such combinations, however, are probably not definite chemical compounds, but mere mixtures.

Weights and Measures.

The weights and measures used for the most part by chemists are the decimal or metric systems, and the chief factors and their English equivalents are as follows:

Capacity:

1 litre = 1,000 cubic centimetres = 35¼ English ounces; and there are about 4½ litres to the English gallon.

1 cubic centimetre (1 c.c.) is equal to 15·43 grains of water at 4° C., and is the standard of the French or metric system of weights and measures.

1 gallon = 70,000 grains.

Weight:

1 gramme (or gram) is the weight of 1 cubic centimetre (1 c.c.) of water at 4° C.

1 milligram is the 1,000th part of a gramme.

1 centigram is the 100th part of a gramme.

1 decigram is the 10th part of a gramme.

1,000 grammes = 1 kilogramme.

1 English lb. = 453·59 grammes, and 1 oz. = 28·35 grammes.

1 gramme = 15·43 English grains.

1 lb. = 7,000 grains.

Length:

1 metre = 39·37 English inches.

1 kilometre = 1,000 metres or about 1,100 English yards.

1 decimetre = the 10th part of a metre.

1 centimetre = the 100th part of a metre.

1 millimetre = the 1,000th part of a metre.

PART II

Force and Energy.

MATTER and force are inseparable. Indeed, the different kinds of matter exist as such by reason of the forces that bind them together in their many forms. They are not distinct things, but, so to speak, part and parcel of each other. There is no force without matter, and no matter without force.

A metal wire is affected by and conducts the electric current; a strip of metal conducts the heat to which it may be exposed from one end to the other, just as in the same way a metal teapot becomes hot outside when boiling water is poured inside. It is through the medium of the matter filling the spaces between, that the light from the sun and the moon is conveyed to the earth. The space between a magnet and iron filings placed upon a sheet of paper, acts as the medium of the magnetic force from the magnet to the iron filings, as evidenced by the iron filings following the magnet when moved from one to another part of the paper.

When a wire of magnesium metal is heated in the air, it burns with an intense white light, and through the space between, the light from the burning metal is conveyed to our eyes.

Force, like matter, is indestructible and unchangeable except as to its form or variety.

Just as matter can be made to change its form or character and properties, so force can be made to change its form and character.

Heat can be changed into light; light can be transformed into heat; electricity can be changed into heat; and all may be converted into mechanical action or power.

Matter may be defined as recognizable substance, and the characters or properties by which we recognize its many varieties may be said to be the expressions given to it by the forces which control it, giving them, in fact, their appearances, their properties and their relations to other substances.

Sugar is a so-called carbo-hydrate, consisting of carbon in combination with the elements of water, and if strong sulphuric acid (oil of vitriol) be allowed to fall upon a lump of sugar, a great chemical change rapidly occurs. The strong acid seizes upon the water elements (forming part of the sugar) with tremendous avidity, and the carbonaceous part of the sugar is set free in the form of a black mass. Some of the water thus seized by the acid, is evaporated owing to the great heat that is given off in the chemical interaction. Now, where does the heat come from? Both the sugar and the acid are cold to start with, yet directly they meet great heat is given off. It must come from the forces which are locked up in the sugar and the acid. What becomes of this heat? Some of it is used in causing the evaporation of the water (given off as steam) which the acid takes out of the sugar. Another part is radiated through the air, for the heat can be felt. In any case, the heat is lost to what was originally a mixture of sugar and acid. In other words, there is a dissipation of energy in the form of heat that was in some way locked up in the two varieties of matter which when placed in contact underwent chemical change attended with the results we have described.

So, again, in the burning of a wire of magnesium metal in the air, not only is great heat given off, but also much bright light, showing that magnesium and oxygen do not consist of mere matter as something distinct from force, but that they are, like all other substances, compounded of the two things.

Mechanical force is capable of bringing about certain chemical changes. For example, a mixture of potassium chlorate and sulphur enters into chemical action with explosive violence when placed upon a hard surface, as of iron or stone, and hit with a hammer, or when rubbed together with a pestle in a mortar. It may be, however, that in such cases, the energy or the friction causes the local emission of heat, as in the striking of matches, and that the heat thus developed is the immediate cause of the chemical changes that are induced. Again, a mixture of hydrochloric acid and phosphine (phosphoretted hydrogen) gases, when exposed to pressure, enters into chemical combination, and there is produced a solid crystalline substance known as phosphonium chloride (PH_4Cl). The same compound is produced also by passing the mixed gases through a tube immersed in a freezing mixture, and it is again dissociated into the originating substances when exposed to the air under normal pressure.

Energy takes a part in every chemical change, but this part is, unfortunately, not revealed by the symbolic equations used by chemists to represent the more material sides of these changes. For example, the equation

$$SO_3 + H_2O = H_2SO_4$$

expresses the formation of sulphuric acid by a combination of sulphuric anhydride and water, but it does not reveal the fact that the combination involves an expenditure of energy disengaged as heat, sufficient to raise the temperature of 213 grammes or cubic centimetres of water from 0° to its boiling-point—100° C.

When water is changed into ice a certain amount of heat is evolved, and, on the other hand, when water is changed into steam a larger amount of heat is absorbed (see pages 43 and 44).

Again, when nitrogen trichloride is suddenly heated, it explodes with great violence and is resolved into its elements,

$$2NCl_3 = N_2 + 3Cl_2,$$

and in this change a tremendous amount of energy is used up in overcoming the atmospheric pressure which acts as a restraining influence.

So it is with every chemical change. The energy that is expended may reappear as heat, or light, or electrical force, or in other form, but there is no absolute destruction or annihilation of energy. All matter being, as it were, made up of substance and force when undergoing chemical change, there is a redistribution but no loss of either substance or energy.

A mass of 772 pounds falling through 1 foot of space produces by friction, sufficient heat to raise the temperature of 1 pound of water 1° F.

The fall of an apple from the tree to the earth, the tidal waves of the ocean, the courses of the planets round the sun and the movements of all the heavenly bodies, are considered to be due to the force known as gravitation.

Light.

Light in Nature is chiefly derived from the sun, but is also furnished by other heavenly bodies. The glowworm and the firefly have the power of giving out a light in the darkness, and, as is well known, decaying animal matter is capable of giving out a pale phosphorescent light. The phosphorescence of the sea is light given out by countless bacteria present in the water.

When a current of electricity is sent through an electric lamp, it gives out light, because the electric current encountering a resistance in its passage through the filament of the lamp, becomes partially transformed into light.

Indeed, by some physicists, light is regarded as identical in essence with electricity.

Lightning, as occurring in storms, is a form of light connected with electric discharges from the clouds. Light can also be produced by chemical means; many substances, such as phosphorus, magnesium, strontium and sulphur, emitting light of different degrees and shades when burned in the air.

In the ordinary combustion of fuel (wood and coal) light is also produced; in fact, combustion of organic matter is always attended with production of more or less light and heat, whilst flame has been described as gas heated to such a temperature that it emits light as well as heat.

When a stream of oxygen mixed with hydrogen is ignited, the mixed gas burns without giving out any sensible amount of light; but if the jet of burning gas be directed upon a piece of lime, the most brilliant light, or so-called *limelight* is produced so soon as the lime becomes hot.

We have another familiar instance of the power of solids to influence the light given out by flame in the so-called Welsbach mantle, in which the burning gas (which in itself would give what is practically a blue flame almost devoid of light) playing upon a surrounding mantle impregnated or charged with certain mineral oxides, develops an intense white light. A mixture of thorium oxide with a small proportion of cerium oxide is commonly used in preparing these mantles.

It is difficult to answer the question, What is light? It is not so much a thing as an effect, a *state* of matter rather than matter itself—that is to say, illuminated matter, varying, of course, with the medium through which it is rendered evident; its revelation being dependent upon what are called undulations or vibrations similar to those of sound produced by blows upon metallic or other bodies and by musical instruments. When a gong is hit by a hammer, it is thrown into a state of excitement or vibration and sound is produced; and in a similar sort of way, when a gas is ignited or when a solid body (as in the case of the limelight) becomes heated in a flame of gas, light is given out in consequence of the burning gas being thrown into a state of tremendous excitement or vibration. The light thus produced is quite distinct from the heat which acts as a first cause or incitement to its production.

When a piece of phosphorus contained in a suitable holder is placed within a jar filled with oxygen at a temperature above 34° C., it takes fire, and emits a brilliant white light (see page 16). As the light does not come from without, it must be the result of the chemical action that takes place between the phosphorus and the oxygen. That being so, it or something that furnishes it, must be contained or locked up in the one or other, or both, of these substances, as explained in the section on Force (see page 35). As a matter of fact, heat always accompanies light, as in the case of the sun's rays.

Light travels at a very great rate—about 185,157 miles in a second—and is only eight minutes in coming from the sun to the earth.

Light is *reflected* when its rays fall upon a mirror—that is to say, it is thrown back at an angle, and may be thus made to show a brilliant spot upon a wall. White light is said to be made up of seven colours—viz., violet, indigo, blue, green, yellow, orange, and red; and if a circular piece of paper be painted with these seven colours in equal sections and made to rotate, or spin quickly, the several colours disappear to the eye, and the whole face of the disc appears to be white.

Light exercises a considerable influence in respect of many chemical changes and particularly those which take place in animal and vegetable tissues.

It is also emitted during the act of crystallization of certain salts from their solutions.

The green parts of plants absorb carbon dioxide gas from the atmosphere under the influence of solar light, the carbon being assimilated or fixed in their tissues, oxygen being at the same time restored to the atmosphere; and this change materially assists in preserving the uniformity of composition of the air we breathe. These changes, however, do not take place when the light is excluded.

A mixture of chlorine gas with hydrogen gas in certain proportions undergoes no chemical change in the dark, but if exposed to sunlight, the two gases enter into combination with explosive violence.

Again, the art of photography depends upon chemical changes brought about on the prepared (sensitized) paper or plate by the direct action of light upon chemicals on their surfaces; solar light having the power of causing decomposition of the oxide, chloride, nitrate or bromide of silver, for example, when these substances (with which their surfaces are prepared) are exposed to it under certain conditions.

The bleaching of linen and other goods by exposure of them to moisture and air is another well-known illustration of the influence of light in effecting chemical changes.

Vegetable matter cannot make its green colouring matter (chlorophyll) without light, and so celery, seakale, etc., are bleached by being kept in the dark.

Heat.

The view taken by Sir Isaac Newton, and still generally accepted, concerning the nature of heat, is that it consists in the internal motions of the particles of bodies—that is to say, movements or vibrations caused by the exercise of energy.

Just as the sun is the chief source of light, so also it is the chief source of heat. Heat can be produced by friction, as is well instanced in the use of machinery, when the parts of metal rubbing against each other are known to become very hot. An indefinitely large amount of heat can be generated by subjecting a mass of brass to friction, and this is illustrated by the great heat that is produced in the boring of metals. As another instance, it may be stated that, when two pieces of ice are rubbed together, sufficient heat is produced to melt the ice.

In all chemical interactions or changes, heat is either given out or absorbed. When quicklime is mixed with water (slaked) it combines therewith, forming a hydrate of lime, and considerable heat is evolved, as evidenced by the generation of steam. In most cases there is an evolution of heat, but in others it is necessary to apply heat to bring about the desired change.

The heat of the human body is produced by the chemical changes that are always going on in it during life.

Light can be changed into heat, and heat has a definite mechanical equivalent. Electricity can also be converted into heat and light, as evidenced by the ordinary electric lamps that are used for lighting purposes, and which become quite warm or hot while in use. The same change is utilized in a larger degree in the construction of electric radiators (for warming), and electrical furnaces.

When solid, liquid, or gaseous substances are heated, heat is absorbed, and for the most part they enlarge or expand, and when cooled they contract.* The wheelwright makes use of this knowledge in affixing iron tyres to wheels, by placing them round the wheels when in a very heated condition, so that upon cooling they clamp by contraction and hold tight to the wooden rims. But, on the other hand, some metals and alloys expand at the moment of setting, and thus give a sharp casting, whereas others contract at the moment of setting and in consequence give a bad casting.

Many solid substances, such as sulphur, camphor, naphthalene and iodine, can be sublimated by heat—that is to say, they can be converted into the state of vapour, and when the vapour is cooled, the substance is re-deposited in the solid form. This is a sort of dry distillation.

Again, many liquid bodies, such as water, can be distilled —*i.e.*, boiled by the absorption of heat and thereby converted into vapour, and when the vapour is cooled again, they are condensed once more into the original liquid form. Ether, alcohol, turpentine, and many other liquids, can be distilled in this way, and the process is often used for purifying the substances employed from associated impurities.

The temperatures at which liquids boil or become vapourized are known as their boiling-points, and these are registered by thermometers.

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* Ice may be very much colder than the surrounding water, but it floats. Water has a maximum density at 39° F., but if cooled below or heated above this temperature, it expands; and but for this, in case of great cold, our lakes and rivers might become frozen solid to the bottom. It is considered by many, that if water had not this peculiar property the world would be unhabitable.

Ether boils at 35·6° C.; alcohol at 78·4° C.; water at 100° C.; turpentine at 160° C.; and mercury at about 350° C.

Temperatures are usually determined in this country according to two scales, but chemists for the most part use what is called the C. or Centigrade scale; the other is known as the F. or Fahrenheit. In Russia, and other parts of Europe, there is still another scale, known as the R. or Réaumur. On the Centigrade scale the freezing-point of water is regarded as zero (0°), and the boiling-point is 100°; whereas on the Fahrenheit scale the freezing-point is 32°, and the boiling-point is 212°.

To convert a Centigrade reading into a Fahrenheit reading, multiply by 9 and divide by 5, and then add 32. To convert a Fahrenheit reading into a Centigrade reading, subtract 32, and multiply by 5 and divide by 9.

SOME NOTABLE TEMPERATURES.

	Centigrade.	*Fahrenheit.*
Theoretical zero of temperature	−273°	−459·4°
Freezing-point of water ..	0°	32°
Mean atmospheric temperature	15·5°	60°
Blood heat	36·6°	98°
Boiling-point of water	100°	212°
Steel melting-point	1350°	2450°
Cast-iron melting-point ..	1530°	2786°
Mercury freezing-point ..	−38·8°	−37·84°
Mercury boiling-point	350°	662°
Red heat just visible in the dark	526°	980°
White heat	1300°	2372°
Oxy-hydrogen flame	2800°	5070°
Electric furnace	3600°	6500°
Arc lamp	4000°	7000°

In the Réaumur scale, the interval between the freezing and the boiling points of water is divided into 80° instead of 100°, as in the Centigrade scale, so that in this case, while the freezing-point is 0°, the boiling-point of water is 80°. To convert Centigrade readings into Réaumur readings, multiply by 4 and divide by 5; and to convert

Fahrenheit readings into Réaumur readings subtract 32, multiply by 4 and divide by 9.

Many metals when heated become converted into the liquid state, and these temperatures are known as their fusing or melting points.

A substance is said to be a good *conductor* of heat when heat is easily transmitted by or through it. For instance, if a copper or iron wire be held by the hand and the other end placed in the flame of a lamp or candle, the heat is quickly conducted from that end to the one held in the hand and can be felt.

A slab of marble or metal feels colder to the hand than a block of wood, because those substances are better conductors of heat and more quickly take heat away from the hand. Charcoal is an instance of a bad conductor, so that a short stick of it can be made red-hot at one end and held by the hand at the other without feeling any pain. Air also is a bad conductor, as are, indeed, all gases. The metals as a class are good conductors.

When water is heated in a closed vessel—that is to say, in such a way that the vapour or steam cannot escape—the temperature of the water goes beyond its ordinary boiling-point and any steam that is generated is held under pressure, the boiling-point of the water increasing with the pressure. Of course, this can only be done in very strong vessels, otherwise they would explode with violence. When water is heated in this way to a temperature of 250° F.—that is, 38° F. above its ordinary boiling-point—the pressure of the steam generated is equal to 30 pounds on the square inch, and the construction of steam-engines is based upon a knowledge of these facts. Steam under pressure as generated in locomotives is used to force down a piston in a cylinder, and this is made to operate on wheels with which it is connected in such a way as to bring and maintain a train in motion.

This illustration will also serve to explain again what has already been referred to when describing force or energy. The great heat generated by the burning fuel used under the boiler, is absorbed by the water and converted into energy or force. That is to say, water which at the ordinary temperature of the air is a quiet harmless liquid, can, by becoming heated in the form of steam, assume an energy so great that, unless the boilers were made of intensely strong material, it would cause them to explode. In other words, the heat is converted into energy, which the water takes up. It is still water, or in other words matter in a very active and forcible state. Illustrations of the conversion of chemical action into energy are also afforded by the explosion of a mixture of petrol vapour and air, as utilized in the engines of motor vehicles and the use of gunpowder. (See Gunpowder, also Explosives.)

It is of importance to note that substances vary very much in their *capacity* for heat. For example, water requires more than twice as much heat to raise it to any particular temperature as does an equal weight of quicksilver (mercury), and this fact in itself is a confirmation of the view we have taken (see page 34), that matter and force are one and inseparable. It is all a matter of *state*, and we only recognize a substance or any particular form of matter by the expressions or properties given to it by the forces which control it—*i.e.*, subject to which it exists.

When a gas, such as carbon dioxide, is liquefied—as it can be—by cooling and pressure, and then allowed to escape by a jet from its container, some part of the escaping gas will absorb heat from the other part, causing it to be deposited in the solid form resembling snow. In a similar way, snow when lying on the ground, during a thaw, will, by absorbing heat from its surroundings, cause ice to be produced in its immediate vicinity. (See also Refrigeration.)

Many chemical actions are brought about by employing the agency of heat, and nearly all kinds of combustion are initially dependent upon its employment. For example, a fire as laid in a domestic grate will not burn unless heat in the form of a lighted match be first of all applied to it.

Heat is all-powerful, too, in breaking up many chemical combinations, causing, in other words, the dissociation of their component parts by overpowering the force by which they are previously united or held together. Even steam can be thus broken up into its component parts (hydrogen and oxygen gases) by the agency, for example, of a piece of platinum metal intensely heated.

Electricity and Magnetism.

Electricity, like heat and light, is a form of force, and is often, if not always, produced as one of the results or accompaniments of chemical action. Indeed, as we shall presently show, it was at one time chiefly produced by chemical means, using what are called voltaic batteries specially constructed for the purpose.

It can be produced by rubbing of certain substances. A stick of sealing-wax, a glass rod, or a piece of amber rubbed briskly upon the coat sleeve become electrified, and the wax or glass in this state can be made to pick up bits of paper by means of electric force.

There are so-called machines which produce electricity by friction, as, for example, when a plate of glass is made to revolve rapidly between two cushions of cloth. An appliance of this kind can be constructed in connection with metallic parts in such a way that the electricity is conducted to a point and discharged therefrom in the form of sparks strong enough to knock a man down.

Lightning is a discharge of electricity (as revealed to our senses by accompanying light and sound) from clouds charged with it; and just as heat can be conducted by metals, so can electricity. It is for this reason that so-called lightning conductors are attached to tall buildings and chimney-shafts to protect them against destruction. These lightning conductors are generally made of copper with pointed ends, and they attract and conduct the electric force into the earth or water with which they are connected at the lower end.

If two plates or rods, one of metallic zinc and the other of metallic copper, be placed in a glass jar containing dilute hydrochloric acid and allowed to touch each other or be connected by, say, a piece of copper wire, a chemical reaction is seen to take place. The zinc is attacked by the acid, although the copper appears to be unaffected; the acid is decomposed and hydrogen gas is given off from the surface of the copper, the zinc having a greater attraction for the chlorine of the hydrochloric acid than the copper. The explanation, so far as it is understood, is complicated; but it may be said that the two metals assume opposite electric states: a current of electricity flows away from the zinc and carries the hydrogen gas to the copper from the surface of which it is discharged. The copper is called the positive pole, and the zinc the negative pole, and, to prove that a current of electricity is really passing from one to the other, it is only necessary, instead of allowing the two plates to touch each other, to connect the two metals under these circumstances with a fine thread of platinum wire instead of one of copper, when—because it is not such a good conductor of electricity, and therefore offers more resistance to its passage—it becomes red-hot, showing that the electric discharge, being impeded or obstructed, is transformed to some extent into heat.

Again, if a strip each of zinc and platinum be dipped in a vessel containing dilute sulphuric acid, little action takes place so long as the two metals do not touch each other; but if they be joined together with, say, a copper wire, the zinc commences to dissolve and hydrogen gas is given off from the surface of the platinum strip, although that metal itself is entirely unaffected by the acid. Meanwhile an electric current passes through the wire, and continues to do so, as long as the action of the acid upon the zinc goes on. This is another instance of chemical change producing electric energy, and such an arrangement is styled a galvanic or voltaic element. The wasting of the zinc furnishes the energy, and the quantity of electricity that passes is proportional to the amount of chemical action, which is represented by the equation

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

A *battery* consists of a number of such elements or cells grouped up together. In this case, the zinc plate, or terminal wire connected with it, is again the negative pole of the battery, and that of the platinum plate from which the electric current starts on its circuit back to the zinc is the positive pole.

In the *Grove battery*, as often used in chemical laboratories, the outer cell (made of glass or ebonite) is charged with dilute sulphuric acid and a zinc plate (the surface of which is amalgamated with mercury to moderate the action of the acid on the zinc), while in the inner, or porous cell, a piece of platinum, immersed in strong nitric acid, serves as the negative pole. The zinc being attacked by the sulphuric acid liberates hydrogen, which in passing through the nitric acid decomposes it, producing water and nitric peroxide (N_2O_4) gas.

Another form of battery not infrequently used, is the *Bunsen battery*, in which the platinum-foil as used in the Grove battery is replaced by a rod of carbon. A third form, however, which finds more general use and is of special service for working electric bells and telephones, is the *Leclanché battery*. In this, zinc-carbon cells are employed—that is to say, each cell consists of a glass vessel in which are placed a block or plate of carbon (charcoal) and a block or rod of metallic zinc, immersed in a solution of sal ammoniac (ammonium chloride, NH_4Cl) dissolved in water. On connecting the carbon and zinc parts with wire, the cells become active and an electric current is generated. In this battery, the zinc, in dissolving, forms a double chloride of zinc and ammonium, and ammonia gas and hydrogen are liberated at the carbon pole. To prevent so-called *polarization*—that is, interference caused by the accumulation of a layer of bubbles of gas on the carbon pole (which would interfere with the satisfactory working of the battery)—the carbon block or plate is packed inside a porous pot with fragments of carbon and powdered manganese dioxide (MnO_2).

An electric current is capable of breaking up or decomposing many chemical substances when in a state of solution, and this process is described as *electrolysis*. For example, a moderately strong solution of hydrochloric acid (HCl) is resolved in this way into hydrogen gas, which is given off at one pole, and chlorine gas, which is evolved at the other pole. Water can similarly be broken up into its constituent parts, and the resulting elements are always produced in their relative or combining proportions—1 part of hydrogen, for example, being accompanied by 35½ parts of chlorine when hydrochloric acid solution is decomposed as above referred to.

The electric current which is generated by chemical or galvanic batteries can be conducted or carried away by metallic wires or rods in the form of a current and utilized as such, or can be transformed into heat, as in electric radiators, or into force by means of electric motors.

The art of electro-plating of metals is dependent upon the deposition of metals from solution on other metals, as effected by the electrolysis of metallic solutions. In silver-plating, for example, the articles to be plated are hung in the solution of a silver salt, and plates of pure silver are also placed in the same liquid, a current of electricity being passed in through the silver plates and out from the iron on other articles to be plated. In this way the pure silver is gradually dissolved, and that metal is deposited as a coating on the spoons, forks, or other articles which it is desired to plate.

As opposed to metals which are good conductors of electricity, other substances show a resistance or incapability of conduction, and such non-conducting materials are used in the construction of so-called *insulators*—for example, the porcelain blocks or cups that are used on telegraph-posts for carrying the electric wires, so that the current is not wasted by being carried or conducted away from the wires.

Magnetism is of the same nature as electricity, and the mineral known as loadstone (magnetic oxide of iron) possesses the power of attracting iron as a natural property. Steel is easily magnetized by contact with another magnet, and, as every boy knows, it then has the property of attracting or drawing towards its poles a needle or piece of iron placed near to it. Nickel and cobalt are also magnetic. Magnetism acts not only at a distance, but also through paper or silk or glass; that is to say, if a needle be placed on a thin sheet of paper or glass, a magnet moved about under the paper or glass attracts and draws the needle in whatever direction it moves. The whole earth acts as a magnet, and its magnetic poles, although not identical with the geographical poles, are in their near neighbourhood. Consequently, the mariner's compass being a magnetized needle and placed upon a pivot, always points one end to the north and the other to the south. The ease with which iron or steel can be magnetized by electricity is utilized, as we shall presently show, in the construction of electro-magnetic machines.

Electric currents are known to exist in the muscles and nerves of animal structures, and are doubtless connected with the chemical changes that are constantly taking place in living bodies. Cats emit electricity, and in dry frosty weather, little sparks can be seen to pass from the standing fur of their coats to the hand when used for stroking them.

Several water-animals produce electric discharges, and in particular may be mentioned the *Raia torpedo* (or electric ray), found in the Mediterranean and Atlantic, which possesses an electric organ on the back of its head; whilst the *Gymnotus electricus* (or Surinam eel) has an electric organ running along the whole length of its body, and is capable of giving a terrible shock.

The discovery by Faraday that currents of electricity can be induced by moving a magnet between the two poles of another magnet has, in course of time, led to the construction of the magneto-electric machines known as *dynamos* or electric generators and electric motors, both of which appliances are now extensively used for many commercial purposes.

Dynamos have, of course, supplanted the use of voltaic batteries in all cases where large applications of electricity are required.

Dynamo-electric machines produce electricity by the rapid rotation of an *armature* made of iron and wound round with coils of insulated wire, between (but not touching) the two poles of a fixed magnet the coils of which are also wound round with coils of insulated wire, it having been found that the magnetism and consequent electric current is intensified by this wrapping of wire. The rotation of the armature, as it is called, can be effected by using the power of waterfalls, or steam, gas and oil engines.

The current of electricity thus generated flows alternately in opposite directions as the coils pass the two poles of the fixed magnet; but a device called the *commutator* (placed on the same shaft as that which carries the armature) has collecting brushes attached to it, and these gather up and cause the current to flow in one and the same direction.

The electric motor is constructed on the same general principle, but in this case, the electric current is used to cause the rotation of the armature, which in its turn is employed as a propellant for the machinery with which it may be connected, and in this way the electricity employed is converted into mechanical power.

The electric *telegraph* enables the user to transmit signals by means of an electric current to distant places, the movements or sounds made at one end of the wire being reproduced at the other end. These movements or sounds are interpreted by an understood code, and in some cases the messages are printed in type or ordinary letters.

The *telephone* is another electric contrivance by means of which an electric current passing through or along a wire reproduces at the far end, or receiver, movements corresponding to those produced in the transmitter by the sound waves of the voice.

Electric lights are of two classes—viz., the *arc* light and the *incandescent* light. In the former the electric current passes from an upper rod of carbon to a lower one across the space which is maintained between them, producing a cloud of carbon vapour which, being intensely heated, forms a luminous arc of flame or light. In incandescent lamps, on the other hand, the filament or thread of carbon or other material which is made luminous is contained within a glass vessel from which all the air has been removed. If these lamps were not exhausted of air, carbon threads would be destroyed by burning—that is, by combination of the carbon with the oxygen contained in the air. As it is, the current flows in at one end of the filament and out at the other and heats it to a state of incandescence. In other words, so much of the electric current is transformed into heat and light in consequence of the resistance offered to its passage. To a very large extent, carbon filaments are no longer used, metallic ones of various kinds having replaced them to great advantage.

The so-called *storage batteries* do not really store up the electric current which is passed into them. What happens is this: the current effects certain chemical changes or decompositions in the contents of the storage cells, and these changes are of such a character that, when the electric current is shut off, the storage cells act as voltaic batteries in consequence of further chemical changes that then take place. In other words, when they are used, they run down or undo the changes effected by the electric charge and restore the elements of these cells to their original condition ready to receive a further charge of electricity.

Electrolytic methods are now largely used in the manufacture of various chemicals, being employed, for example, in the preparation of the metals sodium, magnesium, calcium and aluminium by the electrolysis of fused compounds of these metals; also for refining copper, silver, and gold; the extraction of some metals from their solutions, the manufacture of soda, and the preparation of hydrogen and oxygen gases.

The introduction of the dynamo has also led to the construction of electrical furnaces which are used in connection with the manufacture of graphite, silicon, phosphorus, and many metals and compounds, as also the smelting and refining of certain qualities of iron and steel.

An electric furnace constructed on the principle of the arc light exhibits a temperature of from about 3,000 to 3,500° C., and is used amongst other applications for the production of carborundum. (See Carborundum.)

The electric furnace is also used for the production of calcium carbide (CaC_2). (See Calcium.)

PART III

THE ELEMENTS AND THEIR COMPOUNDS.

The Air or Atmosphere.

THE air we breathe, is not an element nor a chemical compound, but only a *mixture* of gases. Many years ago it was found out that animals which were confined in a limited amount (volume) of air, died after a short time. Later, it was ascertained that in breathing, animals do not consume (use up) all of the air which is inspired (breathed in), but only a part of it, and that part is now known as oxygen; the other part, known as nitrogen, is of no direct use for sustaining life.

Air is a mixture of oxygen gas (about 21 parts) and nitrogen gas (about 79 parts). It really contains small quantities of other gases, also varying proportions of moisture (water) in consequence of the evaporation of water from the land and water surfaces of the earth which is always going on. For any given temperature there is a maximum amount of water vapour which a given volume of air is capable of taking up, and under these conditions it is saturated with moisture at that particular temperature. Instruments which have been devised for determining the amount of moisture contained in a given volume of air are termed hygrometers.

Oxygen gas may be made by many methods, as, for example, from the red oxide of mercury (as mentioned on page 9), also from the black oxide of silver; but it is a *natural* constituent (part) of the air, and in the main the composition of the air is practically the same throughout the world.

Animal life could not exist if this oxygen gas were not present in the air, and the most interesting point is that the air contains such a much larger quantity of the other gas—nitrogen—for even if it were made of oxygen only, we could not live in it. In breathing—the act of inspiration—we suck up or absorb the oxygen of the air (into our lungs), and that reacting upon the blood forms carbon dioxide, which gas is given out in our breath—the act of respiration. The inert nitrogen which is present in the air, makes the oxygen weak or dilute enough to enable this to be done, as oxygen is fatal to human life when continuously breathed in its pure state.

It is the oxygen of the air that also sustains the combustion of coal and coke in our fire-grates. In burning, the carbon of which coal and coke are largely made up (composed) combines or enters into chemical combination with the oxygen of the air, forming carbon dioxide, and gives out heat at the same time. Charcoal is carbon in another form, and if a piece of charcoal be heated to redness and then placed in a globe or glass jar containing oxygen gas, it becomes much brighter in redness, much hotter and gradually disappears, being burnt up (consumed) and thereby converted into carbon dioxide by combining with the oxygen.

This act of burning, or combustion as it is termed, is essentially dependent upon the presence of oxygen. If an ordinary night-light be lighted and placed in a wide-mouthed stoppered bottle, and the bottle be then closed, the night-light will go on burning until the oxygen contained in the air present in the bottle has been used up, when it will go out. On the other hand, as is well known, it will go on burning in the open air until it is all consumed.

In addition to oxygen and nitrogen the air always contains a certain quantity of carbon dioxide, and this constituent is of more importance than might appear without careful consideration, bearing in mind how essential it is to the growth and development of vegetable life, and how the quantity of oxygen contained in the air is maintained by way of compensation. It has been estimated that the amount of carbon dioxide given off in each twenty-four hours through the lungs of an adult human being is that which results from the oxidation of between 7 and 11 ounces of carbon, and this necessitates the consumption of about 1½ pounds of oxygen gas inhaled; and if now we multiply this quantity by the number of the world's inhabitants (human beings and animals), the amount of oxygen gas thus removed from the air is represented by an astounding figure. The quantity, indeed, is so large that unless there existed some compensating process, life would in course of time become impossible on the earth. Upon inquiry it is found that plant life gives back to the atmosphere the oxygen which animal life removes from it. This is the more important because, whereas 100,000 parts of air ordinarily contain about 4 parts of carbon dioxide, 20 or 30 parts would foul it to such an extent as to produce headache and other sickness, while the presence of from 50 to 100 parts would lead to fatal results. Vegetable life absorbs carbon dioxide from the air, as also from the soil and decomposing organic matter, and, assimilating the carbon in its tissues by a variety of chemical processes, gives out again the oxygen which is contained in it, and thus maintains the composition of the air practically constant and universal. The immensity of this process can be imagined when we come to reflect upon the vast extent of forestry and plant life which covers the surface of the earth, and makes us realize at the same time, the great importance of carbon dioxide as a constituent of the air side by side with that of oxygen and nitrogen, its other chief constituents (see also page 67).

Barometers are instruments devised for indicating the pressure and density of the air, and are made in various forms of which the simplest consists of a straight glass tube closed at one end, filled with mercury and inverted with the open end beneath a tray of mercury. It is generally assumed that the average ordinary density of the air is when, at sea-level and at a temperature of zero (0° C.), the column of mercury in the tube stands at 760 millimetres, or 29·92 inches high. As the pressure or density of the atmosphere increases the column rises, and as it diminishes the column falls. The normal pressure is about 14 pounds to the square inch.

Oxygen (O)—atomic weight 16—**and Ozone.**

Oxygen (O)—atomic weight 16—has been known since 1773, and Priestley originally obtained it by heating the red oxide of mercury in the concentrated rays of the sun through the medium of a powerful lens. Associated in combination with hydrogen, it exists also in water (of which it makes up eight-ninths of the weight of that liquid), and it has been roughly estimated to form nearly one-half by weight of the various rocks of which the earth's crust is composed. Oxygen gas is not only yielded by heating the red oxide of mercury—

$$HgO = Hg + O,$$

but a number of so-called peroxides of which dioxide of manganese is typical, yield to the same treatment, thus:

$$3MnO_2 = Mn_3O_4 + O_2.$$

That is to say, the manganese peroxide gives off oxygen gas, and is reduced to a lower state of oxidation when heated to redness.

Barium peroxide (BaO_2) acts similarly:

$$BaO_2 = BaO + O.$$

This change takes place at a temperature of 1,400° C., and when completed the BaO can be reconverted to BaO_2 by exposing it to a current of air at the lower temperature of 700° C. It is upon the basis of these two alternate changes that Brin's method of manufacturing oxygen is based.

Chlorate of potassium ($KClO_3$) when heated to a state of fusion also gives off oxygen, being reduced to the chloride (KCl), Pure oxygen gas is colourless and tasteless, and is slightly soluble in water, fish being dependent upon this dissolved quantity for respiration. In fact, oxygen is the only gas that is capable of supporting respiration.

The oxygen of the air can be separated from the associated nitrogen by chemical means, and it has been found possible to reduce the air to a fluid or water-like state. This is done by pumping the air at a very low temperature and under great pressure into vessels made exceedingly cold. From liquefied air the two gases, nitrogen and oxygen, pass again into the state of vapour at different temperatures; so that it is possible to boil off the nitrogen—or most of it—before the oxygen, and in practice this process is used for the manufacture of liquid oxygen on a large scale.

Liquid air is so cold that when such materials as flesh or india-rubber are cooled in it, they become so brittle that when struck with a hammer they fly into pieces like glass.

Pure oxygen is now an article of commerce, and is not only largely used by doctors for the treatment of many complaints by inhalation, but also for many manufacturing and trade purposes.

In its liquefied form, oxygen gas is of a pale steel-blue shade of colour and exhibits strong magnetic properties.

When oxygen is subjected to the influence of the silent electric discharge, it is converted into what is called an allotropic state and becomes *ozone;* the chemical difference being that whereas the molecule of oxygen contains 2 atoms (O_2), that of ozone (O_3) contains 3 atoms; but the properties of the two substances are perfectly distinct. Ozone is also produced when phosphorus is partially immersed in water and exposed to the air: ozone is formed in the air and hydrogen peroxide (H_2O_2) is formed in the water.

Oxygen is quite odourless, whilst ozone has a peculiar fishy odour and exhibits very superior powers as an oxidizing agent. For example, silver does not suffer oxidation when exposed to pure oxygen, but it is rapidly attacked by ozone and becomes peroxidized. By way of absolute proof that ozone and oxygen are identical in matter, it may be stated that they are mutually convertible, ozone being retransformed into oxygen by raising it to a temperature of 240° C.

Two volumes of ozone give three volumes of oxygen.

Ozone is often found present in small quantity in the air, and doubtless it is formed in lightning discharges when the oxygen of the air is subjected to electrical influences.

Nitrogen (N)—atomic weight 14.

Nitrogen (N)—atomic weight 14—is contained in the air of which it makes about four-fifths, while in combination it occurs in Chile and elsewhere as sodium nitrate ($NaNO_3$) (Chile saltpetre), which is largely employed as a nitrogenous manure or dressing for agricultural purposes. It is also found as potassium nitrate in combination in the form of *nitre* or saltpetre (KNO_3), and as a constituent of many animal and vegetable substances.

Nitrogen can be most readily made from the air by the abstraction of the oxygen, as, for example, by the use of potassium pyrogallate solution which has a great affinity for oxygen, speedily absorbing it from a quantity of air confined in a closed vessel, and leaving the nitrogen unabsorbed.

It can also be made by passing a stream of air over metallic copper heated to redness, when the following interaction takes place:

$$N+O+Cu=CuO+N.$$

That is to say, the oxygen of the air combines with and is fixed by the copper, forming cupric oxide, and nitrogen gas passes over.

Nitrogen is a colourless gas without taste or smell, and is, what is termed, a very *inert* chemical substance. In other words, it is very inactive and exhibits but little tendency to enter into chemical combination with other substances. It can, however, be prepared in a much more chemically active form by an electrical process.

One of the most important combinations of nitrogen is *ammonium* (NH_4), the salts of which are for the most part obtained from the *ammoniacal liquor* of gas-works. The gas liquor is treated with lime and distilled, in which case the ammonia is driven over and condensed as such in water, or passed into sulphuric or hydrochloric acid, forming respectively sulphate, $(NH_4)_2SO_4$, or chloride of ammonium (NH_4Cl), which is also known as sal ammoniac.

Ammonia is also said to be produced on a commercial scale in Germany from a mixture of nitrogen and hydrogen gases contained under pressure and exposed to a high temperature, using a so-called catalytic agent—metallic osmium—to effect the combination. (See Catalytic.)

Ammonium sulphate is largely used as a nitrogenous manure for agricultural purposes and for the manufacture of ammonia-alum (see Alums) and other compounds. It is also extensively used in connection with refrigerating appliances, and for rendering wood and other materials non-inflammable.

Ammonia is very soluble in water which at the ordinary temperature of the air absorbs 727 times its own volume. The solution is colourless, strongly alkaline, and of characteristic odour.

Nitrate of ammonium (NH_4NO_3), as prepared from ammonia and nitric acid, is used in the making of smokeless and flameless explosives.

Sal volatile is a dilute solution of ammonium carbonate.

Nitric acid (HNO_3) is another important compound of nitrogen and is formed in a variety of ways, but the method by which it is in the main produced commercially is by the action of sulphuric acid (H_2SO_4) upon sodium nitrate ($NaNO_3$):

$$NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3.$$

The operation is generally carried out in cast-iron eggs or cylinders lined with fireclay, under the influence of heat, the nitric acid passing over in the form of vapour which is condensed.

There are some six oxides of nitrogen, of which the better known are nitrous oxide (N_2O); nitric oxide (NO); and nitric peroxide (NO_2).

When a current of air is passed rapidly through the electric arc, nitrogen peroxide (NO_2) is formed, and there is an easy way of transforming this product into nitric acid. This process is now used commercially and promises to become of great importance in the future.

Nitric acid is also produced to some extent on a commercial scale by the oxidation of ammonia, and there are considerable expectations based upon this method of production by catalytic processes. (See Catalytic.)

Nitrates in the soil are produced by the slow oxidation of nitrogenous animal matter in the presence of air and an alkali, and this process probably accounts for the natural deposits found in Chile and elsewhere.

Nitric acid when pure is colourless, fumes strongly in the air and is very corrosive in general properties. It exhibits very strong chemical affinities and action, and interacts with oxides and carbonates, forming nitrates of the metals or bases employed.

It is a powerful oxidizing agent and its uses in industrial chemistry are many and of great importance, among others being that of its employment in the manufacture of the explosives, nitro-glycerine, gun-cotton, etc. (See Explosives.)

Hydrogen (H)—atomic weight 1.

Hydrogen does not exist to any considerable extent in nature in the free gaseous state (in which it exists at ordinary temperature), although it is believed to be present in very large amount in the atmosphere of the sun. It is a colourless gas without taste or smell and is the lightest known substance, so that the relative weights of all other elements and substances are generally compared with hydrogen as the unit.

Hydrogen gas is inflammable, and when a stream of it is burned in the air or oxygen gas it forms water by combination, thus:

$$H_2 + O = H_2O.$$

In recent years, hydrogen has been reduced to the liquid state in which it is as clear and colourless as water.

The gas is most easily made by the action of dilute sulphuric acid upon the metal zinc, thus:

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

That is to say, the metal is attacked and dissolved by the acid, forming zinc sulphate which passes into solution, the hydrogen escaping in the form of gas.

A mixture of hydrogen and oxygen gas (or air) in certain proportions is explosive when a light or electric spark is applied to the mixture, water being thus produced in the same way as when a stream of hydrogen is burned in presence of air.

Hydrogen, prepared by various processes, is now largely employed to fill the bags or floating chambers of airships, Zeppelins, etc., also in a number of industries, including the hydrogenation of oils to be used in soap-making. Oils treated by this process are converted into solid fats by the assimilation or absorption of hydrogen. For example, oleic acid ($C_{18}H_{34}O_2$) absorbs 2 atoms hydrogen, and becomes converted into stearic acid ($C_{18}H_{36}O_2$).

The hydrogen for this purpose may be prepared either by passing the vapour of water over iron prepared in a spongy condition, at a high temperature, by which the oxygen is made to combine with the iron and the hydrogen gas is set free; or by the electrolysis of water, in which process the hydrogen is evolved at one pole of the generator and the oxygen at the other.

There are other processes, but these two are the most favoured. The action of the hydrogen upon the oils is brought about by the influence of so-called *catalytic agents* (see page 117), the metal nickel being mostly used for this purpose, although palladium, platinum, cobalt and other metals, have been and can be used.

The catalytic agent is, of course, brought into contact with the oils to be treated and the hydrogen at the same time, and there are many modifications of apparatus or plant for bringing this about.

By this process, many oils otherwise difficult to purify and having objectionable properties are deodorized and turned into solid fats more easily and economically adapted for soap-making, as also for edible use.

Water (H_2O)—molecular weight 18.

Peroxide of Hydrogen (Hydrogen Dioxide, H_2O_2)—molecular weight 34.

Everyone knows what water is. It is known to all in the various forms of rain, snow, and ice; but, unlike the air we breathe (which, it will be remembered, is a mechanical mixture), water is a real chemical compound and consists or is made up of the two elements, hydrogen and oxygen.

Hydrogen and oxygen in their ordinary state are both gases; but when they are made to combine, as, for example, by the action of electricity, they form water.

Two parts of hydrogen (H) combine with 1 part of oxygen (O) and make water, which chemists symbolize with the lettering H_2O, which shows that water is composed or made up of hydrogen and oxygen in these proportions.

Water is found in the liquid state in nature in great abundance; that is its ordinary state, but when frozen it is in the solid state and well known as ice or snow.

In its several forms water makes up about three-quarters of the materials constituting the surface of the earth. It also enters largely into the composition of the tissues of vegetables and animals—to the extent of from 80 to 90 per cent.

It has greater solvent power than any other liquid in respect of variety of substances, and enters largely into the composition (constitution) of many chemical substances, such as hydrates (see page 26) and salts, being combined in the last-named substances as water of crystallization. Copper sulphate, for example, crystallizes in a form containing 5 molecules of water—$CuSO_4,5H_2O$; magnesium sulphate with seven molecules—$MgSO_4,7H_2O$.

Sodium chloride is known in two crystalline forms—viz., $NaCl,2H_2O$ and $NaCl,10H_2O$; whilst sodium carbonate is known in chemical association with water in several forms, including $Na_2CO_3,10H_2O$; $Na_2CO_3,7H_2O$, and Na_2CO_3,H_2O, and so forth.

In many cases the colours of salts are dependent upon the amount of water of crystallization, as instanced by cobalt chloride ($CoCl_2,6H_2O$), which is pink, but when gently heated to 120° C. becomes blue in colour by the loss of its water—hence the employment of the pink compound in the preparation of so-called sympathetic inks, the faintly pink written words becoming visibly blue upon warming of the paper on which they are written.

Another compound—viz., magnesium platino-cyanide in its crystalline form containing 7 molecules of water ($MgPt(CN)_4,7H_2O$)—is of a bright scarlet colour, but when heated to 50° C. it loses 2 molecules of water and becomes $MgPt(CN)_4,5H_2O$, which is of a canary yellow colour, and upon raising the temperature to 100° C. a white salt finally results, having the composition $MgPt(CN)_4,2H_2O$.

Sea-water is impregnated with salts washed out of the earth's surface; has a specific gravity of about 1025 to 1027, as compared with ordinary water, 1000; and contains large quantities of common salt and magnesium chloride. The water of the British Channel contains 28·05 parts NaCl, 3·66 parts of $MgCl_2$, and 4·7 parts of other mineral substances in each 1,000 parts.

Rain-water, as collected in country places where the air is not fouled with smoke and other emanations, is as nearly pure as it can be found in nature, but even then it contains about 2½ volumes of air dissolved in each 100 volumes by measure. (See also Efflorescence, page 4, and Deliquescence, page 4.)

Water as given off from the lungs in respired air by adults in twenty-four hours has been estimated at an average of 311 grammes or nearly 11 ounces.

When water is boiled it takes the form of steam, which is its gaseous state. When water is boiled in a suitable vessel and the steam which is produced thereby is again cooled, it becomes condensed as water once more, and that is known as distilled water.

Many elements and compounds can be distilled in the same way—namely, by heating or boiling—so as to turn them into gas or vapour, and then cooling the gas or vapour so that they return to their original liquid state. Many liquid elements and compounds can also be turned into the solid state by making them very cold.

Rain-water is a sort of distilled water. The heat of the sun evaporates water from the earth and the sea, and then, when the air is more or less saturated with the water vapour and becomes cold enough, it is turned into the liquid state and falls as rain, or snow, or hail.

Water as supplied for drinking purposes, ordinarily contains impurities in the form of substances dissolved out of the earth with which it comes naturally into contact, and is roughly classified as "hard" and "soft" in character. The hardness is mainly derived from the presence of calcium carbonate or chalk in solution, which is deposited as a fur or cake in tea-kettles and boilers. This deposition is due to the expulsion of carbon dioxide, also contained in the water, and which by its presence, and until expelled by the heat, holds the chalk in solution. Such waters may be softened to some extent not only by boiling, but by the addition of lime, which, by entering into combination with the carbon dioxide forms insoluble calcium carbonate ($CaO + CO_2 = CaCO_3$), which is deposited, along with the carbonate previously held in solution by the carbon dioxide thus removed.

Soft water is water which is more or less devoid of substances held in solution, so that freshly collected rainwater is quite soft in character.

Peroxide of hydrogen, or hydrogen dioxide (H_2O_2), is a very interesting substance nearly related to water, and differing therefrom in that its molecule contains 1 atom more oxygen. It can be prepared in a number of ways, one of which consists in mixing barium peroxide (BaO_2) (see page 74) with dilute sulphuric acid, when the following interaction takes place:

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$$

The dilute solution of hydrogen dioxide thus resulting can be concentrated to some extent by evaporation. It is also produced in a number of other ways and is always found amongst the products which result when phosphorus or turpentine are exposed to air and moisture. It also occurs in nature, being found present in the air following lightning discharges and under some other circumstances.

Hydrogen dioxide readily parts with its second atom of oxygen and is a very valuable sanitary and oxidizing agent, being one of the constituents of the disinfecting fluid known commercially as Sanitas Fluid. Solutions of it in water are largely used for bleaching straw, hair, and other articles, also in the practice of surgery, on account of its antiseptic character and its power to destroy the septic matter in bad wounds. It is odourless and colourless like water, to which substance it is reduced when it parts with its active oxygen:

$$H_2O_2 = H_2O + O.$$

Carbon and Coal; Organic Matters.

CARBON (C)—atomic weight 12—is well known in the three forms of the diamond, graphite (plumbago), and charcoal. It is also found widely distributed in nature, not only as a constituent of animal and vegetable tissues (see page 15), and in the air in the form of carbon dioxide (CO_2), but also in combination as calcium carbonate ($CaCO_3$) in the rocks known as limestone and dolomite (see Dolomite). Diamonds are found in many deposits in Brazil, India, South Africa and elsewhere, and are for the most part colourless, but sometimes tinged with various colourings. Minute diamonds have been made artificially on a very small scale, and proved to have the same composition as the natural diamonds.

When strongly ignited, diamonds burn up in the presence of oxygen into carbon dioxide (CO_2), just as charcoal does at a lower temperature, thus proving them to consist of carbon.

Graphite is found plentifully in nature in Siberia, Spain, California, Ceylon and elsewhere, including Borrowdale in Cumberland where it is used in the preparation of pencils. It is a shiny, soft, nearly black substance consisting mainly of carbon, and on account of its refractory character it is used for the manufacture of so-called plumbago crucibles — that is, crucibles made of fireclay mixed with graphite. It is also employed as a polish and coating (blackleading) for iron articles to prevent rusting.

Carbon is also known in impure form as coke, lamp-black and animal charcoal (bone black), and this last-named substance is used in sugar-refining to decolourize the solution, having the property of taking up many kinds of colouring matters.

All vegetable matters consist, in part, of carbon in chemical combination with hydrogen and oxygen, and when they are burned with an insufficient quantity of air or oxygen, a mass of carbon remains behind. For example, when wood is burned in a smothered sort of way—that is, with an insufficient quantity of air or oxygen—a part of it is left behind in the form of wood-charcoal; in fact, that is how charcoal is prepared.

Charcoal has the property of absorbing gases very readily.

In the same way coal, when roasted for the purpose of making coal-gas (used for lighting purposes), is partially converted into coke.

Of course, if there is enough oxygen or air supplied to burning wood or coal, all the carbon becomes consumed by entering into combination with the oxygen, and only the ash is left. This ash consists of mineral matters which were present in the wood and coal before burning.

In burning, coal may be said to give back the heat and light which were originally taken from the sun by the plant-life from which coal is produced.

Vegetable Matters.—There are an immense number of vegetable substances and products, such as sugar, rosin, starch, gum, linseed oil, castor oil, coco-nut oil, various fats, essential oils and colouring matters, all of which consist of chemical compounds of carbon with hydrogen and oxygen. All these products of vegetable life are built up by chemical processes which take place in their living organisms, and are derived from the carbon dioxide absorbed from the soil and air by their roots and other parts—stomata, or small openings on the lower surface of leaves—and this fact demonstrates very forcibly the importance of that substance as a constituent of the atmosphere (see page 55). Many of these products can be, and are, built up by chemists by means of synthetical processes showing that these natural processes are in essence of the same order as other chemical processes, although very complicated and at present imperfectly understood. Amongst the substances that have been produced by chemists may be mentioned formaldehyde, urea, alcohol, glycerine, tartaric acid, indigo, vanillin, alizarin, indiarubber and coumarin (the odoriferous principle of the Tonka bean); also many synthetical perfumes, the manufacture of which has become an important industry.

We may well be excited to wonder by the marvellous extent and nature of the structures (forms), the tissues, the colouring matters and the products that characterize vegetable life, all of which are built up out of the constituents of the soil and the air by the living agencies contained in their seeds. These wonderful processes of nature may be compared with the determining force that causes many salts in a state of solution to crystallize out therefrom in such beautiful geometrical or symmetrical forms as have been referred to in another section. All such compounds—that is, substances of which carbon forms an important constituent—are generally termed *organic*, and most or all of them are combustible—that is to say, they can be burned up if heated sufficiently in the presence of plenty of air or oxygen.

Animal Matters.—Other organic compounds are found to exist in all parts of the flesh, the brains and other parts of animals, but sometimes phosphorus is also found in association, and these organic compounds are even more complex than the others. By animals we mean not only human beings, but all beasts, birds, fishes, and insects.

Carbon forms two compounds with oxygen—viz., carbon monoxide (CO) and carbon dioxide (CO_2). The former is produced whenever carbon is burned with an insufficient supply of oxygen to convert it into the dioxide, and may be prepared in the laboratory by passing a stream of the carbon dioxide gas over charcoal heated to redness: $CO_2 + C = 2CO$. It is a colourless gas having poisonous properties, and is utilized in a process for the manufacture of the metal nickel. (See Nickel.) It occurs at times in coal-mines, and is known as *white damp*. (See Safety Lamp.)

Carbon dioxide has already been described as a constant constituent of the atmosphere and as a product of respiration (see page 54). It is the gaseous product which is obtained whenever carbon is burned with a sufficiency of oxygen, and, like carbon monoxide, is a colourless gas which admits of condensation into the liquid and solid forms. It can readily be produced by the action of acids upon carbonates, such as calcium carbonate (chalk and marble), and when hydrochloric acid is used in this process the change that takes place is represented as follows:

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2;$$

that is to say, the carbon dioxide gas escapes in a brisk effervescence, calcium chloride being left behind in solution. It is employed commercially in various ways, and amongst other applications for impregnating water under pressure, making what is called soda-water.

It is one of the constituents of what is called *black-damp* or *choke-damp* by coal-miners, and often occasions loss of life in mines after explosions. It exists in nature in large quantities in combination in the form of metallic carbonates.

Carbonic acid (H_2CO_3), a combination of carbon dioxide with water ($CO_2 + H_2O = H_2CO_3$), although itself an unstable body, forms by entering into reaction with bases a great series of well-defined compounds known as carbonates. Thus, by combining with the so-called alkalies and alkaline earths, we get the following series:

Sodium, potassium, and ammonium carbonates (Na_2CO_3, K_2CO_3, and $(NH_4)_2CO_3$), all of which are soluble in water.

Calcium, barium, and magnesium carbonates ($CaCO_3$, $BaCO_3$, and $MgCO_3$), all of which are insoluble in water or practically so.

Carbon also combines with sulphur to form the evil-smelling compound known as carbon disulphide (CS_2), which may be prepared by passing the vapour of sulphur over red-hot carbon, the CS_2, which is volatile, being subsequently condensed in vessels properly cooled. Carbon disulphide is manufactured on a considerable scale, and is employed as a solvent of caoutchouc, fats and other substances, also in processes of extraction of essential oils and perfumes, etc.

There are many organic compounds which are composed of carbon and hydrogen only, termed hydrocarbons, including such substances as methane or marsh-gas (CH_4), acetylene (C_2H_2), benzene (C_6H_6), naphthalene ($C_{10} H_8$), and turpentine ($C_{10}H_{16}$).

Cyanogen (C_2N_2) consists of carbon and nitrogen only.

Many others contain oxygen in addition to carbon and hydrogen, and there may be named as examples, alcohol (C_2H_6O), glycerine ($C_3H_8O_3$), acetic acid ($C_2H_4O_2$), and carbolic acid (or phenol) (C_6H_6O).

Another class consists of carbon, hydrogen, and nitrogen, including prussic or hydrocyanic acid (CHN) and aniline (C_6H_7N), whilst yet another class contains oxygen in addition to these three elements, such as urea (CH_4N_2O), indigo ($C_{16}H_{10}N_2O_2$), morphine ($C_{17}H_{19}NO_3$), and quinine ($C_{20}H_{24}N_2O_2$).

There are still more complicated organic substances in which other elements exist in combination with carbon, and one or more of those already mentioned, such as sulphur, phosphorus, chlorine, bromine, and iodine.

The chief solid parts of the living tissues of animals are composed of so-called albumins or compounds containing from 52·7 to 54·5 per cent. carbon; 7 to 7·3 per cent. hydrogen; 15·4 to 17·5 per cent. oxygen; 15 to 18 per cent. nitrogen; and 0·75 to 5 per cent. sulphur, approximately represented by the formula $C_{72}H_{112}N_{18}SO_{22}$.

Inorganic Compounds either do not contain carbon at all or in a comparatively unimportant sense. To this class of bodies most of the natural rocks and earths belong, including the metals and most mineral substances which go to make up the solid parts of the earth (excepting coal and natural mineral oils).

COAL is such an important substance that it deserves a little further study in this place. It is supposed to be the residual product of the natural decomposition of forests and other vegetable matters during enormous periods of time, and is a very complex compound of carbon with hydrogen and oxygen, and generally contains some proportion of nitrogen. There are many varieties of coal, and they are roughly divided into soft and hard coals, the former of which are mainly used for fires and for gas-making, whilst the latter contain more carbon, give out more heat on burning and are more useful for raising steam in boilers.

When coal is burned or roasted, the products of its destructive decomposition which is thus effected, vary according to the temperature which is used and the proportion of air that is admitted. As used for making illuminating coal-gas, other substances are produced and pass away as vapour with the gas, including ammonia, naphtha, coal oils (containing carbolic acid and other compounds), and tar, coke being left as the residual product in the retorts. The volatile products are condensed and separated, and the subsequent re-distillation of the tar yields a further number of products, including pitch, naphthaline, and the bases of many important colouring matters which are of great value in various industries.

About 190 million tons of coal are annually consumed in the United Kingdom, of which about one-fifth part is carbonized in gas-works or in coke ovens for the manufacture of metallurgical coke.

Aluminium (Al)—atomic weight 27.

Aluminium is found very abundantly in nature in a state of combination, but not in the metallic state. Combined with oxygen (Al_2O_3), it forms the substance of the precious stones known as the *sapphire* and *ruby*, both of which are now produced commercially by the fusion of pure alumina in an electric furnace of special construction, and are as good in all respects as the natural gems with which they are identical in composition and properties. In combination with silica it exists as clay, and in another form of combination with iron oxide, it is found in the mineral known as *bauxite* (Al_2O_3,H_2O), from which it is chiefly manufactured by an electrical process. In this process, alumina prepared from bauxite and dissolved in fused cryolite (a double fluoride of aluminium and sodium) is subjected to electrolysis in iron pots lined with carbon, carbon rods being used to carry the current, the power used for generating the electric current (by dynamos) being that of falling waters as utilized at Niagara, the falls of the Rhine at Schaffhausen, and Kinlochleven in Argyllshire.

In this way the aluminium oxide is decomposed, the melted metal collecting at the bottom of the pots and oxygen being liberated at the carbon poles.

The total output of aluminium in the year 1909 has been estimated at 30,000 tons.

The metal aluminium is extremely light, being about one-third the weight of iron, and of the colour of tin. It is very malleable, ductile, does not tarnish when exposed to the air, is a good conductor of electricity, and is extensively used in the construction of many articles both for manufacturing and household employment. Aluminium powder mixed with oil is also used as a paint for iron exposed to the air.

When combined with copper, it makes an alloy known as *aluminium bronze* which makes good castings. This bronze is manufactured by heating a mixture of alumina in the form of *corundum* with charcoal and granulated copper in an electric furnace, in which process the carbon is burned out of the mixture by the oxygen of the alumina (Al_2O_3), and the copper combines with the metallic aluminium, forming an alloy.

Aluminium melts at a temperature of 625° C., and is the essential constituent of the salts or compounds known as alums (see Alums) which have important applications in the industries of dyeing and calico-printing.

Corundum, which is a nearly pure natural oxide of aluminium, occurs in a crystallized form, and is hard enough to cut glass; it is now made by an electric process on a considerable scale, and is largely used for polishing purposes.

Antimony (Stibium, Sb)—atomic weight 120.

Antimony is found naturally in small quantities, but in greater quantities it exists combined with oxygen (Sb_2O_3) as so-called *white antimony*, and in another form (Sb_2O_4) as *antimony ochre*. It is also found in combination with sulphur (Sb_2S_3) as *stibnite*, or grey antimony ore, and with oxygen and sulphur together as *antimony blende*.

Antimony is a bright crystalline metal and is used in making alloys. *Type-metal* consists of lead 75 parts, antimony 20 parts, and tin 5 parts. *Stereotype metal* consists of lead 112, antimony 18, tin 3 parts, and *Britannia metal*, tin 140, copper 3, antimony 9, all of which give fine and sharp castings. Antimony melts at 450° C.

A chemical compound of antimony, commonly known as tartar emetic (a double tartrate of antimony and potassium), is largely used medicinally.

Argon (A)—atomic weight 39·88.

Argon is a recently discovered element found present in the gaseous state in the air in very small proportions—rather less than 1 per cent. by volume.

Arsenic (As)—atomic weight 75.

Arsenic occurs in nature in the metallic state and in combination with sulphur as *realgar* (AsS) and *orpiment* (As_2S_3). It is also found in other combinations with iron, nickel and cobalt. Some of its compounds (such as arsenious oxide As_2O_3) are very poisonous. It is used in the manufacture of flint-glass, also for mixing in small proportion with lead when melted to make shots, which are harder than those made with pure lead. In other forms it is used in the preparation of certain pigments, and as a destructive agent of insects and weeds. Arsenic is of grey colour, sublimes at 450° C., and under pressure it melts between the melting-points of antimony and silver (about 500° C.).

Barium (Ba)—atomic weight 137.

Barium is found in nature in the forms of *heavy spar* or barium sulphate ($BaSO_4$), and *witherite* or barium carbonate ($BaCO_3$). When barium chloride ($BaCl_2$), which is soluble in water, is mixed with a dilute solution of sulphuric acid (H_2SO_4), barium sulphate ($BaSO_4$) is precipitated in an insoluble form—

$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl—$$

and in this form it is largely used in compounding the pigment known as *permanent white.*

Barium sulphide (BaS) is sometimes used as a luminous paint, as it possesses, in common with calcium sulphide (CaS), the property of emitting a feeble phosphorescent light in the dark.

There are two oxides of barium—viz., the monoxide (BaO) and dioxide (BaO_2), the last-named of which is used in the manufacture of hydrogen dioxide (see page 65).

When the monoxide is slaked with water it gives rise to the formation of a hydrate or hydroxide (BaH_2O_2) which is soluble in water and can be obtained in a crystalline form.

Barium nitrate ($Ba(NO_3)_2$) is soluble in water, and is used in pyrotechny for making green fire.

Bismuth (Bi)—atomic weight 208.

Bismuth occurs in nature mainly in the metallic state, also combined with oxygen as *bismuth ochre* (Bi_2O_3), and with sulphur as *bismuth glance* (Bi_2S_3).

It is a lustrous white metal, forming beautiful crystals, melts at about 269° C., and forms alloys with other metals, of which one of the best known is *Wood's fusible metal,* which is made of 4 parts bismuth, 2 of lead 1 of tin, and 1 of cadmium, and melts at 67·5° C.

Bismuth enters into the composition of a number of medicinal preparations.

Boron (B)—atomic weight 11.

Boron occurs naturally in a number of combinations, one of the best known being *tincal*, a crude borate of sodium or *borax* ($Na_2B_4O_7$), and this in a purified form is largely used for cleansing and other purposes. Borax is found naturally in Thibet, California, and elsewhere.

In the elemental state, boron is a greenish-brown powder, but it can be obtained in almost colourless crystals having a density of 2·63.

Boric or Boracic Acid ($B(HO)_3$) is found naturally in the water and steam jets of volcanic eruptions in Tuscany and elsewhere, and is obtained commercially from such sources. It is soluble in water and in a purified condition it finds many medicinal applications, and is largely used as a preservative agent of perishable articles.

Bromine (Br)—atomic weight 80.

Bromine is found in sea-water in combination with potassium, sodium and magnesium, and more abundantly in certain mineral waters and salt springs. The Stassfurt saline deposits of Germany contain it (combined with magnesium) in larger amount in *carnallite*, from which it is chiefly made.

Bromine is a heavy, mobile liquid of a red-brown colour and strong, unpleasant smell. It gives off vapour of the same colour when exposed to the air—that is to say, it is very volatile—and boils at 59° C. It is very poisonous, and has a strong corrosive action on the skin.

The soluble salts, sodium bromide ($NaBr$) and potassium bromide (KBr) are used in the preparation of certain medicinal mixtures.

Cadmium (Cd)—atomic weight 112.

Cadmium is found naturally as sulphide of cadmium (CdS) in a rare mineral called *Greenockite* and in some other forms. It is a bluish-white metal which melts at

320° C. The purified sulphide is insoluble in water and is prepared as a pigment for use in oil and water colour painting.

Calcium (Ca)—atomic weight 40.

Calcium is not met with in nature in the metallic state, but only in combination, and chiefly in the form of carbonate ($CaCO_3$), in minerals such as *limestone*, *marble*, *calcspar*, and *coral*.

In the form of sulphate ($CaSO_4$) it exists as gypsum, and in combination with fluorine as *fluorspar* (CaF_2).

Lime (or so-called burnt lime, CaO) is a combination of calcium with oxygen, and is made on a very large scale by burning limestone with coal in kilns, when the carbonate parts with carbon dioxide and leaves lime or what is commonly known as quicklime behind; thus—

$$CaCO_3 = CaO + CO_2.$$

Or the limestone is baked alone in furnaces at a heat sufficiently great to break it up into quicklime and carbon dioxide gas, $CaCO_3 = CaO + CO_2$, producer gas (see Producer Gas) being used for generating the heat.

This quicklime (CaO), when mixed with water, forms what is known as calcium hydrate or slaked lime (CaH_2O_2).

Lime is used very largely in the making of glass, mortar (see Mortar) and cement (see Cement) and in the preparation of lime-wash and distemper paints. It is also used extensively as the base in the manufacture of chloride of lime or bleaching powder, which is prepared by the action of chlorine gas upon lime; also as a dressing for skins to remove grease and fur, and upon some land or clayey soils, making the land more friable.

Plaster of Paris is calcium sulphate which has been deprived of part of the water with which it combines, by heat, and its constitution is expressed by the formula $(CaSO4)_2H_2O$. It has a great affinity for recombining with more water, with which it sets into a hard mass, and is largely used for lining walls, for moulding and other purposes.

In combination with phosphoric acid, calcium is found present in the bones of animals as calcium phosphate.

When ground lime or chalk is strongly heated with coke in an electric furnace, a compound called calcium carbide is produced (CaC_2), and this product is now made on a large scale for use in the preparation of acetylene gas for lighting and other purposes. (See Acetylene.)

Calcium sulphide (CaS), a combination of calcium with sulphur, exhibits the property of giving out a phosphorescent light in the dark.

Chloride of calcium ($CaCl_2$) is very hygroscopic (see Hygroscopic), and is therefore frequently employed for drying gases by passing them over its surface.

Calcium has been obtained in the metallic state as a whitish metal having a melting-point of 760° C.

Cerium (Ce)—atomic weight 140.

Cerium is found associated with *lanthanum* (another rare element) in the minerals *cerite* and *orthite*, and its oxide (ceria) is used in the making of mantles for incandescent gas burners (see page 38).

Chlorine (Cl)—atomic weight 35·5.

Chlorine is not found in nature in an uncombined state, but exists very extensively in combination with other substances, and most abundantly in the form of common salt or chloride of sodium ($NaCl$). There are large deposits of salt in Cheshire and it forms part of the well-known Stassfurt saline deposits (in Germany). Combined with hydrogen as hydrochloric acid (HCl), it is naturally present in the gastric juice of men and animals. In combination with sodium, as chloride of sodium, it is always found present in sea-water; thus, the water of the English Channel contains 28·05 parts per 1,000. Common salt is mined to some extent in an impure state in the dry condition (rock salt), but for the most part (being soluble in water) it is made by pumping water into the salt deposits and subsequent evaporation of the solution thus prepared.

Chlorine in gaseous form is manufactured on a very large scale, and is employed chiefly in the preparation of chloride of lime, or bleaching powder (see Calcium), which is used very largely for bleaching purposes and as a sanitary reagent. For this purpose it is mostly made by the action of hydrochloric acid upon manganese dioxide (see Alkali Trade Chart):

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

In the Deacon process, which is also employed on a manufacturing scale, a mixture of hydrogen chloride (HCl) gas and air is exposed to the catalytic influence of cupric chloride distributed over a widely exposed surface at a temperature of about 400° C., chlorine and water being produced as follows:

$$2HCl + O = H_2O + Cl_2.$$

It is also employed in the manufacture of potassium chlorate ($KClO_3$) (which is used extensively in match-making and in the preparation of certain explosives) and of chloroform. It has been employed in the condensed (liquefied) state in the recent war for "gassing" of soldiers, it being a very corrosive and poisonous substance. It is of a bright golden-yellow colour, and when cooled sufficiently it freezes to a yellow crystalline mass. It immediately passes into the gaseous state when liberated in the air, and has a very violent action on the linings of the mouth, nose, throat, and lungs, causing death when inhaled in serious quantity.

Chlorine is best known in the state of gas, being of a greenish-yellow colour and nearly two and a half times heavier than air. It is somewhat soluble in water, forming a green solution.

Metallic copper in thin leaf form, metallic antimony in the form of powder, and sodium, all take fire and burn readily in chlorine gas, forming chlorides, although the gas itself is not inflammable. Similarly a jet of burning hydrogen gas will continue to burn in a vessel containing chlorine gas, thus producing hydrochloric acid in the form of white fumes:

$$H + Cl = HCl.$$

Hydrochloric Acid, or hydrogen chloride (HCl), is one of the most important compounds of chlorine. The two gases hydrogen and chlorine do not combine when mixed together in the dark, but in sunlight or electric light they combine with explosive violence. The acid can be easily prepared, amongst other methods, by the action of strong sulphuric acid upon common salt as represented by the equation

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

This is to say, sulphate of sodium and hydrochloric acid are produced, and the hydrochloric acid can be distilled over from the mixture in the form of gas and condensed in water, thus furnishing a solution of the acid. In its gaseous form, the acid is colourless and possesses a pungent, irritating character. It is extremely soluble in water, which at 0° C. and under ordinary atmospheric pressure dissolves (or absorbs) 503 times its own volume.

Hydrochloric acid is manufactured from common salt and sulphuric acid as a by-product in the manufacture of sodium carbonate, the gas (HCl) being absorbed in condensers by the action of water percolating down towers or stacks packed with broken coke (see Alkali Trade).

Hydrochloric acid decomposes the oxides of the alkaline and other metals, as also their carbonates, as illustrated by the following equations—the first representing the action of the acid upon sodium oxide (Na_2O), the second that of the acid upon barium oxide (BaO), and the third that upon ferric oxide:

$$Na_2O + 2HCl = 2NaCl + H_2O,$$
$$BaO + 2HCl = BaCl_2 + H_2O,$$
$$Fe_2O_3 + 6HCl = 2FeCl_3 + 3H_2O,$$

the chloride of the base being produced in each case. Carbonates of the same and many other bases are similarly decomposed. For instance, using sodium carbonate the change is as follows:

$$Na_2CO_3 + 2HCl = 2NaCl + H_2O + CO_2;$$

and barium carbonate as follows:

$$BaCO_3 + 2HCl = BaCl_2 + H_2O + CO_2.$$

Chromium (Cr)—atomic weight 52.

Chromium occurs in nature in combination in a number of minerals, including chrome iron ore (*chromite*, Cr_2O_3FeO, which is the main source of preparation of chromium), *crocoisite* ($PbCrO_4$), and *chrome ochre* (Cr_2O_3).

In the metallic state, chromium is a hard steel-grey metal and is employed to some extent for the purpose of imparting hardness and tenacity to steel used for making tyres, springs, axles, and armour plate.

Many of the compounds of chromium are used as pigments, *chrome green* being an oxide of chromium of the composition (Cr_2O_3), while *chrome yellow* is lead chromate ($PbCrO_4$). Pure metallic chromium is less fusible than platinum and as hard as corundum.

Cobalt (Co)—atomic weight 59.

Cobalt occurs in nature in several combinations with arsenic. It is a nearly white and hard metal, and forms salts which in solution have a blue or pink colour. *Smalt* which is a combination of cobalt with silica, is used to some extent as a pigment.

Copper (Cuprum, Cu)—atomic weight 63·5.

Copper is found in many places in the metallic state, and even in large masses in some North American and Siberian mines. It also occurs in nature in the form of *copper pyrites*, or double sulphide of copper and iron ($Cu_2S.Fe_2S_3$). The Rio Tinto, Mason, and Barry ores are of this description.

Copper ore is also found in Australia in the form of carbonate, and as oxide and sulphide in Cuba, while that from Chile is associated with a valuable proportion of silver. *Malachite* is a native carbonate of copper.

When the oxide of copper is used for production of the metal, it is smelted in a blast-furnace with coal or coke, by which it is reduced as shown by the equation:

$$Cu_2O + C = CO + 2Cu.$$

That is to say, the oxygen of the copper oxide enters into combination with the carbon of the coal or coke, forming carbon monoxide, and the metallic copper thus produced is afterwards refined by other processes.

With other ores of copper containing sulphides, different processes are employed.

Most of the copper-smelting in this country is carried out at Swansea.

Copper melts at 1091° C., and is one of the most useful metals. It has a reddish colour, is rather hard, tenacious, ductile and malleable, and, apart from its employment in the form of wire for telegraphic purposes (on account of its excellent conductivity), it is largely used for making domestic utensils, coins, sheathing of wooden ships, etc. It enters into the composition of many alloys; for example, with various proportions of tin, it forms *bronze*, *bell-metal*, and *gun-metal*, while *brass* is an alloy of about 2 parts of copper with 1 part of zinc, and *Muntz metal* is an alloy of 3 parts copper with 1 part zinc. Its compounds (oxides and salts) are largely used in compounding various pigments.

A solution of oxide of copper in ammonia is used in the preparation of Willesden paper and artificial silk. (See Cellulose.)

Copper sulphate ($CuSO_4.5H_2O$) is the most important salt of copper and is formed when the metal or its oxide is dissolved in sulphuric acid. It is soluble in water and when such a solution is concentrated by heat and allowed to cool, the sulphate crystallizes out in fine blue crystals containing 5 molecules of water, as shown by its formula.

It is used as a mordant in dyeing, and in making a number of preparations which are used for the destruction of low forms of insect pests on vines and other plants.

Fluorine (Fl)—atomic weight 19.

Fluorine is found in nature combined with calcium in the mineral *fluorspar* (CaF_2)—also known as *Derbyshire spar*—and is a constituent of *cryolite* (Na_3AlF_6) and other minerals.

Fluorine, at ordinary temperatures, is a pale yellowish gas of very active chemical, corrosive and poisonous qualities, and in particular it attacks glass with avidity. When condensed to the liquid state it is a mobile yellow fluid with a characteristic odour something like that of chlorine.

A combination with hydrogen known as hydrofluoric acid (HF), which is very soluble in water, is largely employed for etching purposes, as, for example, making the graduations on glass measuring apparatus. The object to be marked in this way is coated with wax, and after making the design or marks on the coated glass, it is exposed to the action of the acid either in the form of gas or liquid, with the result that the glass is eaten into where exposed (by the markings), thus forming the design or marks desired, the fluorine having no action on the wax.

Hydrofluoric acid is made by the action of strong sulphuric acid upon powdered fluoride of calcium:

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

Gold (Aurum, Au)—atomic weight 197.

Gold is widely distributed in nature and is found for the most part in the free or metallic condition in quartz veins and alluvial deposits resulting from the gradual disintegration of gold-bearing rocks. It is extracted from quartz by crushing and amalgamation with mercury, and from alluvial deposits by mechanical washing with water, the water carrying away the lighter associated substances and leaving the heavier gold behind. When the amalgam process is used, the gold is obtained from the amalgam (see page 32) by distilling off the mercury, the gold being left behind.

There are other methods of extracting gold from its ores, in one of which potassium cyanide (KCN) is used on a very large scale. The crushed ore containing gold in a finely divided condition is treated with a solution of the potassium cyanide containing from ¼ to 1 per cent. of that chemical agent while freely exposed to the air. This dissolves the gold, which is afterwards precipitated from the solution by means of metallic zinc or by electrolytic action, using lead-foil anodes for that purpose.

When zinc is used, the solution containing the gold in the form of a double cyanide of potassium and gold undergoes chemical change as follows:

$$2KAuCy_2 + Zn = K_2ZnCy_4 + 2Au.$$

That is to say, the zinc replaces the gold in the double cyanide and the gold is set free.

Gold is comparatively soft, yellow in colour, and the most malleable and ductile of all metals, admitting of being beaten into an extremely fine form of leaf, which is used for gilding and other purposes. It can be beaten out into sheets so thin that 280,000 are required to make one inch in thickness. Gold is not attacked by acids, with the exception of aqua regia (nitrohydrochloric acid), in which it dissolves, forming auric chloride ($AuCl_3$). It melts at 1037° C.

Alloyed with copper and silver, it is largely used for coinage and other purposes. Pure gold is described as 24 carat gold, whilst 18 carat gold consists really of 18 parts of gold and 6 parts copper or silver. In this country the legal standard is 22 carat gold.

Electro gilding of other metals—that is, the deposition or coating of them—is carried out by using a solution of the double cyanide of gold and potassium (see page 48).

Helium (He)—atomic weight 4.

Helium is the name given to a recently discovered substance supposed to be of elemental character contained in the air in extremely minute quantity and in certain mineral spring-waters, notably those of Bath. It is also found in association with a large number of mineral compounds of uranium, thorium, and other rare earths. It is a colourless gas of very light character, ranking next to hydrogen in this respect. It is also said to be a disintegration product of radium emanation; but if that be correct, then, of course, radium cannot be regarded as an element.

Iodine (I)—atomic weight 127.

Iodine is widely distributed in nature, being found in compound form associated with potassium, sodium, magnesium and calcium, and is present in sea-water and seaweed, as also in *caliche* or Chile saltpetre (sodium nitrate). It is prepared to some extent from kelp (ashes from seaweed), but chiefly from the Chile saltpetre above named, which contains less than $\frac{1}{4}$ per cent.

The seaweeds which contain most iodine are of the so-called "drift" order—viz., *Laminaria digitata* and *Laminaria stenophylla*, each of which contains a little less than $\frac{1}{2}$ per cent.

Iodine is a blue-black, shining substance, easily obtained in crystalline form, which melts at 107° C., and is then vapourized, the vapour having a beautiful violet colour. It has a characteristic penetrating odour, and is only slightly soluble in water, but readily soluble in a solution of potassium iodide, alcohol, etc.

In general properties it strongly resembles its family neighbours chlorine and bromine. Dilute solutions of it in water and alcohol are used in surgery as antiseptics, whilst potassium iodide (KI) is extensively employed as a medicament.

Iron (Ferrum, Fe)—atomic weight 56.

Iron occurs in nature in the form of many ores. Magnetic iron ore, or *loadstone* (FeO, Fe_2O_3), is a compound of oxides of iron from which much of the best Swedish iron is made. Red *hæmatite* (Fe_2O_3) is largely mined in some parts of Lancashire, Cumberland and to some extent in Cornwall, while large deposits exist near Bilboa in Spain and elsewhere. It is greatly used in the manufacture of Bessemer pig iron.

Brown hæmatite ($2Fe_2O_33H_2O$), a hydrated oxide of iron, is the source of much of the iron made in France and Belgium, whilst enormous quantities of *clay ironstone* (which is an impure carbonate of iron containing about 33 per cent. of iron, and the poorest of the iron ores that are worked) are used in this country as a source of iron. Iron also occurs naturally as carbonate in the forms of *blackband* of the Scotch coalfields, and in an impure form in the neighbourhood of Northampton. Iron as manufactured and dealt in commercially is not a pure metal, and varies very much in composition and qualities according to the purposes to which it is to be applied. Some of the better-known kinds are named cast iron, wrought iron, foundry iron, forge iron, steel, etc., and their melting or fusing points and other properties vary with the composition.

Cast iron is made in blast-furnaces from mixtures of iron ore with coal or coke and limestone, by which means the oxygen contained in the oxides or other iron compounds is burned off by the carbon, leaving metallic iron. The molten iron settles in a layer at the bottom of the furnace, the *slag* remaining on its top. "Pig iron" made in this way contains from 2 to 5 per cent. of carbon and small quantities of sulphur, phosphorus and silicon. Cast iron is used for making stoves, saucepans, iron gates and a number of other articles. It is hard and brittle, and more readily fusible than wrought iron, which is made from it, and which is fusible only at a white heat.

Wrought iron when heated, however, to redness is soft, and can be hammered and joined (welded) into any desired shape, a property which is utilized in smithery.

The purest form of commercial iron is the fine malleable quality of which wire is made.

So-called "slagwool" is made from slag by blowing steam against it when in melted form, being thereby converted into fine threads like cottonwool, and in this form it is used as a covering for steam-pipes and boilers, and as a packing material.

Steel is produced from wrought iron by the incorporation of carbon to the extent of from 0·7 to 1·7 per cent., and from cast iron by removing the excess of that impurity, and is, in practice, mostly produced by either blowing or otherwise exposing molten cast iron to a blast of air which burns out the carbon. So-called mild steel contains from 0·1 up to about 0·4 per cent. of carbon; the harder varieties contain up to about 2 per cent., while the amount of carbon that iron can be made to take up is just over 4 per cent., corresponding to the formula Fe_5C.

In the manufacture of steel for industrial employment many other metals are deliberately introduced, manganese, for instance, being used for hardening purposes up to about 1 per cent. in the so-called Bessemer and open-hearth steels, although for some purposes larger quantities are used; while nickel is used to produce a toughening effect, and chromium, tungsten, molybdenum, tantalum, and vanadium, are employed to give particular properties or qualities to steels destined for special applications.

The *hardening* is brought about by the rapid cooling of steel which has been heated to a high temperature, whilst the *tempering* of steel is effected by reheating the hardened metal to a temperature much lower than that used for hardening it, and cooling slowly.

Slag (known as Basic Slag) resulting from the manufacture of iron and steel containing phosphorus finds great employment, when reduced to powder, as a fertilizing agent, and is a promising source of potash.

Sulphate of iron ($FeSO_4,7H_2O$) is used in making inks and other articles, whilst many of the other salts of iron are used in medicine and the arts, some of the oxides being employed largely in making pigments and for polishing glass and other articles.

Lead (Plumbum, Pb)—atomic weight 207.

Lead occurs naturally for the most part, in the form of *galena* or sulphide of lead (PbS), England and Spain providing the principal supplies.

Lead is produced by several processes, one of which consists in roasting the lead sulphide in a reverberatory furnace at a certain temperature, whereby some of it is resolved into lead sulphate ($PbSO_4$) and some into lead oxide (PbO), a part of the sulphur being burnt off as sulphur dioxide (SO_2). Upon increasing the temperature a further change takes place in the mixture, which still contains some lead sulphide, and metallic lead results from the two following interactions:

$$PbSO_4 + PbS = 2Pb + 2SO_2$$
$$2PbO + PbS = 3Pb + SO_2.$$

The metallic lead thus produced is subsequently refined by another process.

Lead melts at 325° C. and is a bluish-white metal very soft in character, but not very ductile or tenacious, and it readily tarnishes upon exposure to the air. Owing to its soft character it is easily worked and it is consequently employed very largely for making cisterns, water-pipes, gutters and roofing, as also shots, and in the preparation of various alloys. *Type-metal* consists, for example, of lead alloyed with about one-third of its weight of antimony, and lead is also used in the manufacture of *fusible metal*, *pewter* and other alloys. *Solder*, as used by plumbers and tin-plate workers, is a mixture of lead and tin in proportions varying with the particular applications to be made of it, whilst so-called *pot-metal* is an alloy of lead and copper.

Many of the compounds of lead are largely used in the arts and manufactures.

White-lead, which is used so much in compounding paints and putty, is hydrated carbonate of lead with, or without, admixture of oxide of lead.

Of the various processes for making white-lead the oldest and best is the so-called Dutch process, which depends upon the use of acetic acid in association with moist air and carbon dioxide. The lead, prepared in a way to present as large a surface as possible by being cast into rough gratings or grids, is placed in and on pots which are placed over a bed of spent tan-bark, the acetic acid being placed in the pots. The acid is slowly vapourized by the heat of the fermenting tan, and this, acting upon the lead, forms a compound basic acetate, which undergoes further changes by the carbon dioxide evolved from the fermenting tan, and the action of air and moisture, finally resulting in the production of white-lead of commerce.

Red-lead is a compound of the oxides of lead, and is largely used in the manufacture of flint-glass and for other purposes, whilst lead sulphate ($PbSO_4$) and lead chromate ($PbCrO_4$) are both used in compounding paints and pigments.

Litharge, or oxide of lead (PbO), is used in connection with the manufacture of oils and varnishes, and in the manufacture of certain qualities of glass and pottery.

Most of the lead salts and compounds are very poisonous.

Lithium (Li)—atomic weight 7.

Lithium is a somewhat rare element found in small quantities widely distributed in nature, in association with certain more or less rare minerals. It is also found in several mineral waters which are extensively used for medicinal purposes.

Lithium in the metallic form is the lightest known solid substance; it is of a soft character and has a silver-like appearance, but quickly tarnishes when exposed to the air. It melts at 180° C.

In combination with oxygen as lithium oxide (Li_2O), it exhibits alkaline properties, and both in this form and that of carbonate it finds medicinal application as an antidote to gouty complaints.

Magnesium (Mg)—atomic weight 24.

Magnesium is not found uncombined in nature, but exists abundantly in combination associated with calcium as a double carbonate in the form of the mineral *dolomite.*

Magnesite is a form of carbonate ($MgCO_3$), and *kieserite* is magnesium sulphate ($MgSO_4,H_2O$). *Carnallite* is a double chloride of magnesium and potassium ($MgCl_2.KCl.6H_2O$), and it is from this substance that magnesium in a metallic form is chiefly produced by an electrical process.

Magnesium is a silver-white metal which tarnishes slightly upon exposure to the air, melts at a red heat and readily takes fire when heated in the air, combining with the oxygen thereof and forming magnesium oxide (MgO). This burning is attended with a brilliant white light often used for photographic purposes.

Several of the salts of magnesium are used in medicine, particularly the sulphate, or *Epsom salts* ($MgSO_4$); whilst the oxide has peculiar value for metallurgical purposes, such as the manufacture of crucibles and cupels. Magnesium has a melting-point of 633° C.

Manganese (Mn)—atomic weight 55.

Manganese is found in nature chiefly in the form of *pyrolusite*—a black oxide (MnO_2). It is not well known or extensively used in the metallic state, except as a hardener of steel as made for certain special applications.

Manganese ore—the black oxide—is largely used in the manufacture of chlorine by the action of hydrochloric acid, the chlorine in turn being used for the manufacture of bleaching-powder (chloride of lime). (See Calcium and Alkali Trade.)

The higher oxides of manganese are useful sources of oxygen gas. Two compounds of manganese with potassium and oxygen are well known as potassium permanganate ($KMnO_4$) and manganate (K_2MnO_4), both of which are used as sanitary reagents, being valued on account of their oxidizing properties.

The manganate is made by fusing black oxide of manganese together with potassium hydrate or carbonate, from which the green product is obtained by dissolving in water, whilst the red permanganate is now chiefly made by the electrolysis of the manganate solution at a temperature of about 60°, using iron electrodes.

Mercury (Hydrargyrum, Hg)—atomic weight 200·6.

Mercury (quicksilver) occurs in nature to some extent in the free or globulous state admixed with its ores, particularly the sulphide, of which *cinnabar* (HgS) is the best known. It is found in Spain, California, and Bavaria.

Mercury is made from the natural sulphide by roasting the ore, whereby the sulphur is burnt off as sulphur dioxide (SO_2), or by heating the ore mixed with lime in closed retorts. In this last-named process, the lime combines with the sulphur, whilst the mercury is liberated and distils over as vapour which condenses upon cooling into the well-known liquid form.

Mercury is a bright silver-coloured metal which upon freezing, solidifies to a crystalline condition. When submitted to long heating in the air, it is slowly converted into the red oxide of mercury (HgO). It forms several other combinations with oxygen, and some of its salts are very poisonous.

Mercuric chloride ($HgCl_2$), or *corrosive sublimate*, as it is also known, has very powerful antiseptic and germicidal properties, and for this reason it is used by taxidermists in preparing the skins of animals, also by surgeons in dilute solution as an antiseptic wash. Another chloride of mercury, mercurous chloride (*calomel*, $HgCl$), is used in medicine.

In the form of *vermilion*, mercuric sulphide (HgS) is largely manufactured for use as a pigment.

Mercury combines readily with many other metals forming alloys or combinations which are called amalgams (see page 32). Tin amalgams are used in making mirrors, while amalgams of tin and copper are used in dentistry as fillings or stoppings for teeth.

Molybdenum (Mo)—atomic weight 96

Molybdenum is contained in the mineral called *molybdenite* which is a sulphide of the metal (MoS_2) found in Bohemia and Sweden; also in *molybdenum ochre* which is an oxide of the metal (MoO_3), and *wolfenite*, a compound oxide of lead and molybdenum ($PbMoO_4$).

Upon roasting the native sulphide in a current of air, the sulphur is burnt off as sulphur dioxide (SO_2), an oxide of molybdenum being left behind, and by mixing this with oil and charcoal and then strongly heating the mixture the molybdenum is reduced to the metallic state. The metal is white, brittle, and is difficult to fuse.

Nickel (Ni)—atomic weight 59.

Nickel occurs in combination in a number of minerals, chiefly in combination with arsenic as *kupfernickel* (Ni_2As_2), *white nickel* ($NiAs_2$), *nickel glance* ($Ni_2(AsS)_2$), and *nickel blende* (NiS). It is, however, chiefly made, and in large quantity, from the mineral *garnierite* (which is found in New Caledonia) by a roasting process, in which the sulphur and arsenic constituents are for the most part burned off, the resulting mixed metallic oxides being subsequently heated in a stream of so-called "producer gas" containing carbon monoxide. (See Producer Gas.) By this process they are reduced to the metallic state other than the nickel, which enters into combination with the carbon oxide and passes off in a vaporous state, from which the nickel is obtained by passage through a pipe heated to about 180° C., whereby it is resolved into the gas (which is used over again in fresh operations), and the free metal, which is deposited in a lustrous mirror-like form.

In the free elemental state it is best known as a black powder, but it can be obtained in the metallic state and is then a bright lustrous white metal of very hard character and high melting-point. It is used, amongst other applications, for toughening steel and in the manufacture of alloys for making coins in Germany, Belgium, France and the United States. It is also extensively used for plating iron and steel articles and in connection with a process for hardening oils by hydrogenation. (See Hydrogen.)

Palladium (Pd)—atomic weight 106·7.

Palladium is a rare metal which is found associated in platinum ores to the extent of from ½ to 1 per cent.

It is white, fairly ductile and malleable and melts at a somewhat lower temperature than platinum. It is interesting on account of its capability, under certain circumstances, of "occluding" gases. If, for example, a wire of palladium be made the negative pole of a Voltaic cell, it will in course of the decomposition of water absorb as much as 936 times its own volume of hydrogen gas, during which time it increases very largely in bulk. A piece of foil of the metal will, when heated to between 90° and 97° C., in an atmosphere of hydrogen, absorb as much as 643 times its own volume of that gas.

Phosphorus (P)—atomic weight 31.

Phosphorus is not known to occur in nature in its free or uncombined state, but in combination with metals and oxygen it is widely distributed, being found most abundantly in the form of phosphate of calcium. *Sombrerite* is a phosphate of calcium ($Ca_3(PO_4)_2$). *Apatite* is a natural combination of phosphate and chloride of calcium, whilst *wavelite* is a phosphated compound of aluminium.

Phosphorus as found present in fertile soils is derived from the disintegration (breaking down) of phosphatic rocks, and is not only essential to the growth of plants, but is also found present in many of the human tissues, more particularly the bones and the brain, the former of which contain as much as about 60 per cent. of phosphate of calcium. Indeed, *bone-ash*, which consists almost entirely of calcium phosphate, is one of the chief sources from which phosphorus is made.

In the elemental state, phosphorus is a slightly yellow-white semi-transparent and wax-like substance which takes fire when warmed and exposed to the air (see page 38), so that it has to be kept submerged in water. In its ordinary form it is very poisonous. It melts under water at 43·3° C. and is soluble in carbon disulphide (CS_2) from which it may be obtained upon evaporation in the form of colourless crystals. It may also be sublimated *in vacuo* and obtained in beautiful crystals.

Phosphorus forms many compounds, and in the form of soluble phosphates, phosphoric acid enters into the composition of many medicines.

The natural phosphates, with or without treatment, are largely used in agriculture as manures. When treated with sulphuric acid, they are decomposed, the sulphuric acid combining with the base and phosphoric acid being set free. For example, *bone-meal* and *sombrerite* ($Ca_3(PO_4)_2$), when treated in this way, undergo decomposition as expressed by the equation:

$$Ca_3(PO_4)_2 + 3H_2SO_4 = 3CaSO_4 + 2H_3PO_4.$$

Phosphorus is allotropic—that is to say, it can be made to assume more than one form. When heated to between

240° and 250° C. out of contact with the air, it passes into a red form, which, unlike the ordinary yellow phosphorus, is not luminous in the dark and is not poisonous, and in this form it is largely used in connection with the use of matches. These are tipped with a mixture of potassium chlorate, potassium dichromate, red-lead and antimony sulphide, and when rubbed over a surface of red phosphorus and antimony sulphide, as spread over the sides of the safety-match boxes, take fire by friction.

Phosphorus is also used in the preparation of rat-poison and in the manufacture of *phosphor bronze.*

Phosphorus forms several compounds with hydrogen, the better known of which is hydrogen phosphide (also known as phosphine), PH_3. It is formed when red phosphorus is gently heated in a current of hydrogen gas, and is also produced by the action of water upon calcium phosphide—

$$3Ca_2P_2 + 12H_2O = 6CaH_2O_2 + 4PH_3 + 2P.$$

This phosphoretted hydrogen is a colourless gas of an offensive odour and highly poisonous character, which takes fire at a temperature below that of boiling water.

Calcium phosphide is employed in the construction of drain-testers, and the action of water upon that substance finds practical employment also in the marine appliance known as Holmes's signal. In the case of the drain-testers it is the distinctive odour of the gas that enables the operator to detect leakages in drains, whilst in the case of Holmes's signal the phosphoretted hydrogen ignites and burns, giving a considerable illumination.

Platinum (Pt)—atomic weight 195.

Platinum is found in nature in small grains and nuggets in river sand and alluvial deposits in Brazil, Borneo, California and the Ural Mountains; also in association with some other rare metals including osmium and iridium.

It is of a bright greyish-white colour, is malleable and ductile, does not tarnish in the air and is heavier than gold. It is largely used in chemical laboratories in the form of crucibles, small dishes, foil and wire, because it is not acted upon by most chemicals. Platinum is also extensively employed for electrical purposes, and by jewellers in making valuable ornaments. It can be melted by the oxyhydrogen flame.

Platinum dichloride ($PtCl_2$) is used to some extent in the platinotype photographic process.

Potassium (Kalium, K)—atomic weight 39.

Potassium occurs most abundantly in nature at Stassfurt in Germany in the form of saline deposits of various compositions—viz., as chloride (KCl) in *sylvine*, as a double chloride of potassium and magnesium ($KCl.MgCl_26H_2O$) in *carnallite*, and as a double sulphate and chloride ($K_2SO_4.MgSO_4.MgCl_26H_2O$) in *kainite*. It is also found in the soil as a product of decomposition of certain rocks (for instance *felspar*), from which it finds its way into vegetable life and so into the bodies of the animals that feed upon it. This accounts for the presence of potash in the *suint* or fat that is extracted from sheep's wool.

In the form of nitrate (KNO_3) it is also found in association with sodium nitrate in the nitrate deposits of Chile and Peru.

The metal potassium is silver-white, lustrous and soft. It melts at 62·5° C., and rapidly oxidizes in the air, so that in the metallic state it is usually preserved in naphtha. In common with sodium, it decomposes water, hydrogen being liberated as follows:

$$H_2O + K_2 = K_2O + H_2.$$

The K_2O becomes dissolved in the excess of water, forming a solution of potassium hydrate, or caustic potash, as it is also called:

$$K_2O + H_2O = 2KHO,$$

i.e., a combination of potassium oxide and water.

Potassium chlorate ($KClO_3$) is a crystalline body which is manufactured on a considerable scale—chiefly by the electrolysis of potassium chloride in a state of solution—for use in the preparation of explosives, matches and fireworks.

Potassium carbonate (K_2CO_3) was originally obtained from the ashes of wood—hence the name "pot-ashes," and it is still extracted from this source in some parts of Canada and the United States of America, where timber is abundant.

Potassium cyanide (KCN) is largely used as a solvent of gold in certain methods of extracting that metal from its natural sources (see Gold).

Caustic potash (KHO) is extensively used in the manufacture of soft soaps.

Potassium nitrate, or *nitre* (KNO_3), also known as *saltpetre*, is largely used as a fertilizer and in the manufacture of gunpowder, which is a mixture of nitre, charcoal and sulphur in proportions of about 75, 15 and 10 respectively.

It may here be noted that the explosive power of gunpowder is due to the enormous evolution of gas from a small quantity of solid, the nitre supplying the oxygen necessary for burning up the carbon and the sulphur and yielding nitrogen gas. (See Explosives.)

Radium (Ra)—atomic weight 226.

Radium has not been isolated in the metallic state and is one of the more recently discovered elements, the chief source of which is *pitch-blende*, a mineral found in Cornwall and elsewhere. It has remarkable properties and is supposed by some to be an atomic decomposition product of the metal uranium. It yields salts, of which the bromide, chloride and iodide have been described and all of which are luminous in the dark.

The radiations of radium are used as a curative agency in medical science and its rays are very destructive of animal tissues. It is also liable to spontaneous decomposition, in process of which it gives out heat continually, and yields another substance described as helium, so that its elemental character is a matter of much doubt.

Selenium (Se)—atomic weight 79·2.

Selenium is met with in nature associated with sulphur as a selenide of sulphur, and is interesting inasmuch as it affords a striking instance of an element which has the capability, like sulphur and phosphorus, of assuming several distinct forms. In other words, it is allotropic and can be obtained in an amorphous form, in a vitreous form and in a crystalline form.

It is a good conductor of electricity, and its conductivity is increased by light.

Silicon (Si)—atomic weight 28.

Silicon is one of the most abundant and widely distributed substances in nature. Combined with oxygen as silica (SiO_2), it is found and well known in the forms of *flint, sand, quartz, rock crystal, agate, jasper* and *chalcedony*. In other combinations, it helps to make up the composition of clay, soil and many rocks. (See Clay.)

Silicon is not a metal, but when obtained in the elemental state it is known both in the forms of a brown powder and in a crystalline condition of metal-like appearance. In the form of sand, silica is used very extensively in the manufacture of glass of all descriptions.

A combination of silicon with carbon is known as carborundum. (See Carborundum.)

Silica occurs in nature also in combination with water (SiO_23H_2O) in the form of the precious stones known as *opals* and in a commoner form as *kieselguhr* (the silicious remains of so-called Diatomaceæ). Quartz crystals find uses not only as gems, but also for certain optical purposes, while silica in combination with sodium, as silicate of sodium (water-glass) in the form of solution, is sometimes employed for preserving stone facings of buildings from atmospheric attack. To understand this application it may be explained that many stone buildings are composed of natural limestone ($CaCO_3$), and the carbon dioxide and water which are always present in the air have a destructive solvent action upon such facings (see Calcium). This can be prevented to some extent by washing with silicate of sodium, as the silica enters into combination with the calcium of the limestone, forming on the surface a thin layer or coating of silicate of calcium which is not subject to the same destructive influence. Water-glass is also largely used in the preservation of eggs, the eggs being made air-tight by coating their surfaces with the solution, thus preventing the access of air-borne germs.

Glass is a mixture of silicates of potassium or sodium with one or more other silicates which are insoluble in water, such as silicate of calcium, magnesium, etc. In practice, ground quartz or flint or clean sand, mixed with potassium or sodium carbonate and the other ingredients, are fritted together in an oven or furnace, by which means the silica constituting the quartz or sand enters into combination with the bases, thus forming glass.

There are many and very great varieties of glass, differing from each other in their respective compositions, qualities and uses. When the mixture used for glass-making consists only of sodium carbonate, calcium carbonate and sand, the two carbonates first of all fuse together, and then at a higher temperature they are decomposed by the silica (of the sand), the two bases combining therewith, whilst carbon dioxide is evolved.

Window glass is made by fusion from a mixture of sand, sodium carbonate or sodium sulphate and limestone in fireclay pots.

Bohemian glass is made from pure potassium carbonate and powdered quartz, and is not so fusible as window glass.

Flint glass is made from ground flint, lead oxide, and potassium carbonate, and is very fusible.

Fused silica or quartz glass of opaque and transparent characters is now largely used in the construction of chemical apparatus, as it only melts at about the same temperature as platinum, and is very resistant to the action of chemicals.

Silver (Argentum, Ag)—atomic weight 108.

Silver occurs in nature in the metallic state and also in combination in a number of minerals—for example, in *argentite* or *silver glance* as silver sulphide (Ag_2S), in *horn silver* as chloride ($AgCl$), and as silver sulphide associated with other metallic sulphides.

The crude silver as prepared from its sources is purified by one process, by amalgamation with mercury, followed by distilling off the mercury, which leaves the refined silver behind; but there are a number of other methods which are adapted to the several requirements according to the composition of the ore from which the silver has to be obtained.

Silver is a white metal which is not acted upon by the oxygen of the air, but is tarnished when sulphuretted hydrogen is present in the atmosphere, due to the surface formation of silver sulphide. Silver articles thus coloured are commonly but erratically described as "oxidized" silver.

It is a good conductor of heat and electricity and is very malleable and ductile. It melts at 1,000° C. Alloyed with copper, it is largely used for coinage and other purposes, including electro-plating. The British standard for coin is 92½ per cent. silver and 7½ per cent. copper, pure silver being too soft to use alone for this purpose. (For Electro-Plating, see page 48.)

Many of its salts are employed in photography and otherwise.

Silver nitrate ($AgNO_3$) is the well-known *lunar caustic*.

Sodium (Natrum, Na)—atomic weight 23.

Sodium, like potassium, is one of the alkali group of metals, and in the form of chloride of sodium is best known as a constituent of sea-water which contains an average of about 28 parts per 1,000.

Sodium chloride ($NaCl$), or common salt, occurs in nature in large deposits in Cheshire, Lancashire and elsewhere, whilst sodium nitrate ($NaNO_3$) is the principal constituent of *caliche*, or *soda nitre*, which is found in large quantities in Chile and Peru and which is exported to the extent of some two million tons annually, having great value as a fertilizing agent on account of its richness in nitrogen.

In the purified state, salt forms a very valuable food for men and animals.

The metal sodium is now made in large quantity by the electrolysis of fused caustic soda at a temperature of about 20° C. above its melting-point, and is used largely in other manufactures, including that of indigo as prepared synthetically.

Metallic sodium is very like potassium in most respects, being soft and white, and decomposes water with considerable violence on being thrown into it.

$$Na_2 + H_2O = Na_2O + H_2,$$

the Na_2O, or sodium oxide, dissolving in the excess of water and forming sodium hydrate or caustic soda—

$$Na_2O + H_2O = 2NaHO.$$

Caustic soda is largely manufactured for use in many chemical applications, especially in the making of soap, being capable of decomposing fats and oils, thus liberating the glycerine which these bodies contain, and combining with the fatty acids (their other constituents). Soap, in other words, is a combination of soda with fatty acids.

Much of the caustic soda that is manufactured is still made from common salt by various chemical processes, but an increasingly large amount is now commercially made by the Castner-Kellner and other processes of electrolysis of brine or strong solution of common salt (NaCl) in water.

Sodium carbonate (Na_2CO_3) is the basis of washing-soda (soda crystals), which is so largely employed for detergent and cleansing purposes, and this compound in its several commercial forms is also obtained from common salt by a number of chemical processes. (See Alkali Trade.)

When common salt (NaCl) is subjected to the action of strong sulphuric acid at a temperature of about 120° F., it is resolved into sulphate of sodium and hydrochloric acid which escapes as gas and is subsequently condensed and dissolved by the action of water.

In the so-called Le Blanc process, crude sodium carbonate is made by furnacing sodium sulphate (produced as above described) with chalk or limestone or lime and small coal, when a number of chemical changes take place of which a general view is indicated by the equation:

$$Na_2SO_4 + 2C + CaCO_3 = CaS + 2CO_2 + Na_2CO_3,$$

sulphide of calcium being formed together with the carbonate of sodium which is afterwards dissolved out of the fluxed mass with water and purified. (See Alkali Trade.) Larger quantities are, however, now made by the ammonia process, in which sodium chloride and hydrogen ammonia carbonate (so-called ammonium bicarbonate) are made to interact in such a way as to result in the formation of ammonium chloride and hydrogen sodium carbonate (bicarbonate of sodium)—

$$(NH_4)HCO_3 + NaCl = NaHCO_3 + NH_4Cl.$$

In this process a brine solution is saturated with ammonia gas, and the liquid is then charged with carbon dioxide gas, and in this way the sodium bicarbonate, being less soluble, separates out, whilst the ammonium chloride, which is more soluble, remains in solution, and the ammonia is afterwards recovered from it by the action of lime—

$$2NH_4Cl + CaH_2O_2 = CaCl_2 + 2NH_4HO.$$

Sodium sulphate (Na_2SO_4) is found naturally in the form of the mineral *thenardite* and as *glauberite*, which is a double sulphate of sodium and calcium.

Many of the salts of sodium are used in the arts and in medicine, and sodium nitrate, in particular, is employed as an agricultural manure, also in the manufacture of gunpowder and fireworks, and as the chief source of nitric acid (HNO_3), (see page 59).

Strontium (Sr)—atomic weight 87·6.

Strontium is contained in the mineral known as *strontianite* in the form of carbonate ($SrCO_3$), and in *celestine* as sulphate ($SrSO_4$).

The metal is of a pale yellow colour, readily oxidizes in the air and possesses the property of decomposing water.

Like magnesium, it burns brilliantly upon ignition in the air.

One of its compounds—viz., strontium hydroxide ($Sr(OH)_2$)—is used on a large scale in the purification of sugar, with which it forms a combination (saccharate of strontia) which can be decomposed by carbon dioxide.

The nitrate of strontium ($Sr(NO_3)_2$) is extensively employed in the production of red fireworks. Some strontium salts are used for medicinal purposes.

Sulphur (S)—atomic weight 32.

Large quantities of sulphur are found naturally in volcanic districts including Italy, Sicily and Iceland, and there are considerable beds of it in China, India and California. Sulphur is also found naturally in various forms as sulphides of which the best known are *galena*, or lead sulphide (PbS), *zinc blende*, or zinc sulphide (ZnS), and *pyrites*, or iron sulphide (FeS_2).

Cinnabar is a natural mercury sulphide (HgS). The mineral *gypsum*, or calcium sulphate, contains sulphur in combination with calcium and oxygen and water ($CaSO_4.2H_2O$), whilst *heavy spar* also contains sulphur in the form of barium sulphate ($BaSO_4$).

Sulphur affords one of the most interesting examples of substances which can assume a number of varying or so-called allotropic forms. In its ordinary form it is a yellow crystalline body of octahedral formation, but by melting it under certain conditions it can be obtained in the form of prismatic needles of transparent character, which upon exposure to the air gradually lose their transparency, crumble up and assume once more the form of octahedra.

The influence of heat upon sulphur is quite remarkable. It melts at 115° C. to a yellow, limpid (thinnish) liquid; but if the temperature be allowed to rise to almost 186° C., it becomes quite viscid (thick) and darkens very much in colour. If the heat be continued up to about 260° C., it again becomes more fluid, but not so fluid as when first melted, and if now it be allowed to cool suddenly (as by pouring it into cold water), it solidifies into a soft mass which can be drawn out into elastic threads. This form can be again transformed into the original by heating it to 100° C., when it suddenly returns to the brittle condition with an evolution of heat. This change also takes place if it is kept for a short time.

When sulphur is distilled in small quantities and the vapour allowed to condense in a vessel not artificially cooled, it takes the form of red oily drops which remain fluid for some hours, but afterwards passes into the solid condition.

It may be sublimed—that is to say, it can be volatilized or made to assume the form of vapour, which can then be condensed into the solid state.

At one time sulphur was largely used in the making of matches, but this has been superseded by other methods. It is used in the manufacture of gunpowder and sulphuric acid (H_2SO_4), also for vulcanizing rubber (see Vulcanite)' and in pharmacy in compounding so-called milk of sulphur and other medicaments.

Sulphur burns in the air with a blue flame, and gives rise to the production of sulphur dioxide (SO_2), a gas which may be condensed and liquefied or a solution of it in water can be prepared. In all three forms it is used as a disinfecting agent; also as a bleaching agent in connection with straw, silk, wool and sponge.

Another well-known combination of sulphur (with hydrogen) is that of so-called sulphuretted hydrogen (H_2S), a strongly offensive smelling gas which is found in nature in volcanic areas and also in many mineral waters, such as Harrogate.

Carbon disulphide (CS_2) is described under Carbon (see page 69).

Sulphuric acid (H_2SO_4), or oil of vitriol, is one of the most important compounds of sulphur and is manufactured from sulphur dioxide—as produced by the roasting of pyrites (containing sulphide of iron and copper), or by burning sulphur in the air—and oxidation of the sulphur dioxide (SO_2) vapour in contact with moisture (water vapour) by the agency of gaseous nitric peroxide, thus:

$$2SO_2 + N_2O_4 + 2H_2O = 2H_2SO_4 + 2NO,$$

the sulphuric acid thus produced being absorbed or dissolved in water. In other words, through the agency of the nitric peroxide the SO_2 is made to take up an extra atom of oxygen, and this, in combination with water, furnishes sulphuric acid—

$$SO_2 + O + H_2O = H_2SO_4.$$

The nitric peroxide is obtained from nitric acid, which in turn is produced by the action of strong sulphuric acid (H_2SO_4) upon sodium nitrate ($NaNO_3$) or soda nitre; thus—

$$2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3.$$

In this process, the nitric peroxide (N_2O_4) gives up some of its oxygen, being reduced to nitric oxide (NO), which becomes peroxidized again by the air, yielding anew the N_2O_4, which serves again for the same purpose. (See Alkali Trade).

In the pure state, sulphuric acid is a heavy, colourless, oily body of very corrosive properties, having a great affinity for water, and behaving with the oxides and carbonates much in the same way as hydrochloric and nitric acid, forming the corresponding sulphates. It is made in enormous quantities and finds employment in a great number of industrial applications.

Tantalum (Ta)—atomic weight 181·5.

Tantalum is a rare element found in nature in association with another rare element (niobium) in the Swedish mineral *columbite* or *tantalite*. It has a very high melting-point and is used in making electric lamp filaments.

Thorium (Th)—atomic weight 232.

Thorium is a rare metal occurring in the Norwegian minerals *thorite* and *orangeite*, and in the form of an oxide it is used in the preparation of mantles for use with incandescent gas burners. The purer thorium compounds are worked up from the raw material called monazite sand, which occurs naturally in extensive deposits in Carolina and the coast of Brazil.

Tin (Stannum, Sn)—atomic weight 118.

Tin is found in nature for the most part in the form of oxide (SnO_2), in the mineral known as *tin-stone* in Cornwall and elsewhere. The metal is prepared from it by a process of calcination with anthracite coal, whereby the oxygen constituent is removed in the form of carbon monoxide and the metal remains behind in the form known as block tin—

$$SnO_2 + 2C = 2CO + Sn.$$

Tin is a bright white metal which does not tarnish in the air and melts at about 231° C.

It is largely used in the process of tinning iron and other metals, ordinary tin-plate consisting of sheet-iron coated with tin on the surface by dipping the cleaned iron plates into the molten tin. It is easily melted and has valuable applications by reason of the fact that it is not acted upon by many chemicals which readily attack iron and some other metals. It enters into the composition of many alloys, including *solder*, brasses and bronzes. *Britannia metal* is sometimes made of 84 parts tin, 10 parts antimony, 4 parts copper and 2 parts bismuth (see also page 73); whilst pewter consists of 4 parts tin and 1 part lead.

Tin chloride ($SnCl_2$) is used as a mordant.

Titanium (Ti)—atomic weight 48·1.

Titanium is a rare element occurring in several mineral forms (*rutile*, *brookite*, and *anastase*), and finds some employment in metallurgy.

Tungsten (T) or **Wolfram** (W)—atomic weight 184.

Tungsten is a metal which is highly prized for use in hardening and toughening steel as specially made for metal-cutting tools, also for making the filaments used in the so-called Osram lamp. It occurs in nature as *scheelite*, or tungstate of calcium ($CaWO_4$), and also as *wolfram*, which is a double tungstate of manganese and iron.

Uranium (U)—atomic weight 238.

An oxide of this metal is contained to the extent of 40 to 90 per cent. in the mineral *pitchblende* which is found in some Cornish mines. It is a silver-white metal in appearance and melts at a nearly white heat.

Some uranium componnds are employed to give a yellow fluorescent coloration to glass.

Vanadium (V)—atomic weight 51.

Vanadium is a somewhat rare metallic element which occurs naturally in some minerals, including *vanadite*, *pucherite* and *mottramite*, all of which are of complicated chemical composition.

Vanadium has a commercial importance in connection with the manufacture of certain kinds of steel, to which a very small proportion—little more than ½ per cent.—contributes tensile strength and certain other special properties of much value for some particular applications.

Zinc (Zn)—atomic weight 65.

Zinc is not met with in nature in the metallic state, but occurs as *calamine* (zinc carbonate, $ZnCO_3$) in Silesia, and it is also worked in Belgium. *Blende* (Zinc sulphide (ZnS)), is found and worked to some extent in England, while in New Jersey a red zinc oxide is found in considerable amount; but the chief supply of spelter (as zinc is also known) comes from Australia.

Zinc melts at 418° C., boils at 930° C., and can be distilled at 1,040° C.; it is a crystalline metal, has a bluish-white appearance; is fairly ductile and malleable, and only tarnishes slightly in moist air.

The zinc of commerce is produced by a process of distillation from a mixture of the oxide of that metal with carbon ($2ZnO + C = 2Zn + CO_2$). The metal is largely used for roofing and galvanizing (coating) iron, to which it gives durability by preserving it from atmospheric oxidation. Zinc also enters into the composition of many alloys, of which *brass* is the best known (2 parts copper and 1 part zinc).

Zinc oxide (zinc white) is used as a pigment, having the advantage of not being blackened by exposure to the air when sulphuretted hydrogen is contained therein, and the salts of zinc are employed, some for medicinal purposes and some in various industries. The soluble salts of zinc are poisonous.

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A paste made by moistening zinc oxide with zinc chloride rapidly sets into a hard mass, and this so-called oxychloride of zinc is used by dentists as a stopping and filling for teeth.

Zirconium (Zr)—atomic weight 90·6.

Zirconium is a rare element found in nature in the form of silicate ($ZrSiO_2$) in the mineral *zircon*. The oxide, zircona, is a valuable refractory material, and, amongst other applications, is employed in the preparation of mantles for incandescent gas lamps.

PART IV

DICTIONARY AND INDEX

Absorbent—Capability of absorbing or soaking up.

Acetic Acid ($C_2H_4O_2$)—An acid forming the active principle of vinegar, which is readily prepared by the oxidation of ordinary alcohol and by fermentation of alcoholic liquids. It is also extracted from the products of the dry distillation of wood.

Acetone (C_3H_6O)—Is a mobile colourless liquid obtained, amongst other methods, by the dry distillation of acetates such as barium and calcium acetates. It is largely used as a solvent of gun-cotton and celluloid bodies.

Acetylene (C_2H_2)—Is a gas produced from calcium carbide (see page 77), by allowing water to drop on that material as contained in a suitable generator, and this may be connected with a gas-holder in which the gas can be stored over water.

When acetylene gas is burned in conjunction with oxygen in blow-pipe form, a very high temperature is obtained—higher, indeed, than that of the oxy-hydrogen flame and used, amongst other applications, for cutting through armour plates up to 6 inches in thickness.

Acids—See page 25.

Adhesion—The action of holding particles together.

Aerial—Character of air.

Affinity—See page 10.

Agate—See page 97.

Air—See page 53.

Air-Pump—An appliance for withdrawing or pumping air or other gas from or into a vessel.

Alabaster—A native form of calcium sulphate.

Albumin—See page 70.

Alcohol—Spirits of wine of indefinite alcoholic strength. (See also Methylated Spirit and Proof Spirit.)

Absolute Alcohol (C_2H_6O)—A colourless, volatile, inflammable liquid (freed from water), the product of the fermentation of sugar (glucose) and the active principle of spirits (gin, whisky, brandy, rum), wines, and beers.

Alizarine ($C_{14}H_8O_4$)—An important colouring matter prepared from the roots of the madder plant, and now made on a large scale by a synthetical process from anthracene.

Alkali—See page 26.

Alkali Metals—See page 14.

Alkali Trade—For general chart of processes employed, see opposite page.

Alkaline Earth Metals—See page 14.

Alkaloids—A nitrogenous class of organic substances including atropine, nicotine, quinine, morphine and strychnine, constituting valuable medicinal agents.

Allotropy—Capability of assuming various forms. (See also pages 57, 93, 97 and 103.)

Alloys—See pages 32, 72, 73, 81, and 92.

Alluvial Action—The action of water and air on rocks and other mineral formations. (See Clay.)

Aluminium—See page 71.

Aluminium Bronze—See page 72.

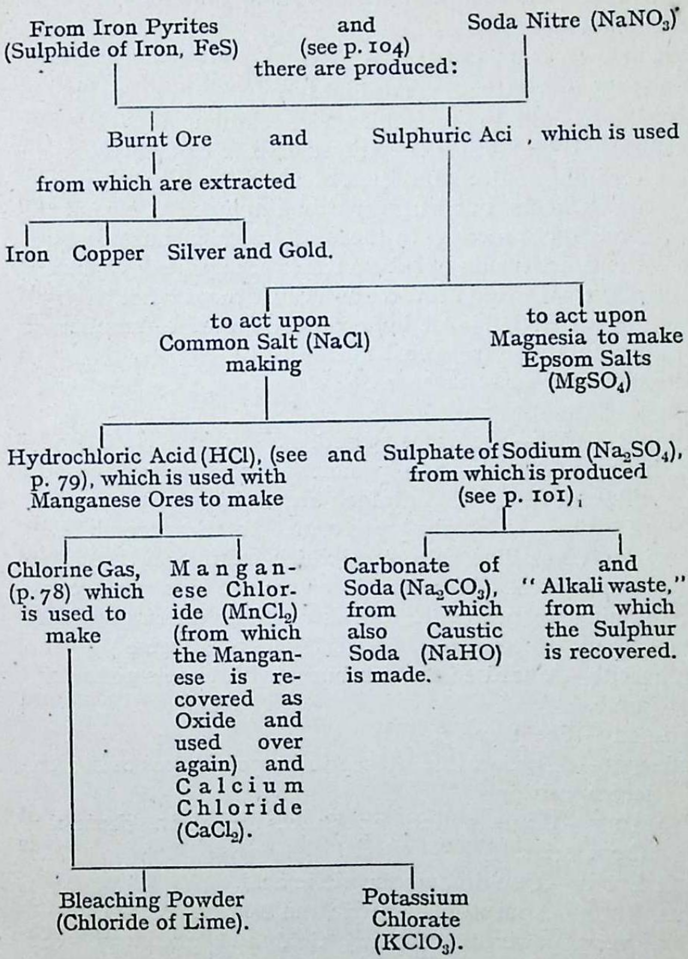
Alums—So-called alums are double salts (sulphates), of which potassium alum ($Al_2(SO_4)_3K_2SO_4,24H_2O$) is illustrative.

Amalgams—See pages 32, and 91.

Amber—A yellow rosin-like substance found on the seashore in many places, and as a fossil in alluvial soils.

Alkali Trade—

General Chart of Processes Employed.



From Iron Pyrites (Sulphide of Iron, FeS) and (see p. 104) Soda Nitre ($NaNO_3$) there are produced:

Burnt Ore and Sulphuric Aci , which is used

from which are extracted

Iron Copper Silver and Gold.

to act upon Common Salt (NaCl) making

to act upon Magnesia to make Epsom Salts ($MgSO_4$)

Hydrochloric Acid (HCl), (see p. 79), which is used with Manganese Ores to make

and

Sulphate of Sodium (Na_2SO_4), from which is produced (see p. 101)

Chlorine Gas, (p. 78) which is used to make

Manganese Chloride ($MnCl_2$) (from which the Manganese is recovered as Oxide and used over again) and Calcium Chloride ($CaCl_2$).

Carbonate of Soda (Na_2CO_3), from which also Caustic Soda (NaHO) is made.

and "Alkali waste," from which the Sulphur is recovered.

Bleaching Powder (Chloride of Lime).

Potassium Chlorate ($KClO_3$).

Ambergris—A product obtained from the intestinal tract of the sperm whale, and greatly valued by perfumers.

Amethyst—A native form of silica coloured with iron oxide.

Ammonia Soda Process—See page 101.

Ammonium and its Salts—See page 59.

Amorphous—Without crystalline form. (See pages 5 and 28.)

Analogous—Having resemblance or relation.

Analysis—This word is sometimes used to express the same meaning as decomposition of a substance into its parts or elements, but as ordinarily employed it means the process or processes by means of which chemists find out the constituents of substances. (See pages 9 and 20.)

Anhydrous—Devoid of water as a constituent. (See page 5.)

Aniline ($C_6H_5NH_2$)—An important base of a number of dyes derived from coal-tar.

Animal Charcoal—See page 66.

Animal Life—See page 55.

Animal Matter—See pages 15 and 68.

Anthracene ($C_{14}H_{10}$)—Is a product of the destructive distillation of coal, contained in coal-tar to the extent of from ¼ to nearly ½ per cent. In the pure state it is a crystalline substance which exhibits a fine blue fluorescence. It occurs in commerce as a paste containing 50 per cent., and is used for making aniline colours, especially *Turkey Red*. (See Alizarine.)

Anthracite—A hard coal which burns with little smoke and flame.

Antimony—See page 73.

Antiseptic—A preventive of septic or putrid poisoning or decomposition.

Apparatus—Utensils and appliances used in chemical laboratories.

Aqua Fortis—An old name for nitric acid.

Aqua Regia—A mixture of nitric and hydrochloric acids—a very powerful solvent. Gold and platinum, for example, can be dissolved by this mixture.

Aqueous Vapour (Atmospheric)—Is the water or moisture held dissolved or in solution in the air (see p. 53.)

Argol—Crude tartar as deposited in wine-casks or at the bottoms of fermenting vessels.

Argon—See page 73.

Arsenic—See page 73.

Asbestos—A fibrous variety of the mineral *amphibole*, being a compound silicate and aluminate of magnesium, calcium and iron.

Asphalt—A natural deposit of solid bitumen.

Astringent—Bitter, harsh taste.

Atmosphere—See page 53.

Atomic Weights—On page 13 there has been given a list of the better-known elements together with their approximate atomic weights as ordinarily accepted and used, and the following is a more complete list with the international atomic weights as given for the year 1917. These atomic weights are revised year by year in the light of the most recent investigations, oxygen being taken as the standard at 16, the atomic weight of hydrogen then becoming 1·008. See also pages 10, 13, and 21.

COMPLETE LIST OF THE ELEMENTS, WITH THEIR SYMBOLS AND INTERNATIONAL ATOMIC WEIGHTS. 1917.

(Oxygen [16] being taken as the standard).

	Symbol.	Atomic weight.		Symbol.	Atomic weight.
Aluminium ..	Al	27·1	Cobalt ..	Co	58·97
Antimony ..	Sb	120·2	Columbium	Cb	93·1
Argon ..	A	39·88	Copper ..	Cu	63·57
Arsenic ..	As	74·96	Dysprosium	Dy	162·5
Barium ..	Ba	137·37	Erbium ..	Er	167·7
Bismuth ..	Bi	208·0	Europium ..	Eu	152·0
Boron ..	B	11·0	Fluorine ..	F	19·0
Bromine ..	Br	79·92	Gadolinium	Gd	157·3
Cadmium ..	Cd	112·40	Gallium ..	Ga	69·9
Cæsium ..	Cs	132·81	Germanium	Ge	72·5
Calcium ..	Ca	40·07	Glucinum ..	Gl	9·1
Carbon ..	C	12·005	Gold ..	Au	197·2
Cerium ..	Ce	140·25	Helium ..	He	4·00
Chlorine ..	Cl	35·46	Holmium ..	Ho	163·5
Chromium ..	Cr	52·0	Hydrogen ..	H	1·008

	Symbol.	Atomic weight.
Indium	In	114·8
Iodine	I	126·92
Iridium	Ir	193·1
Iron	Fe	55·84
Krypton	Kr	82·92
Lanthanum	La	139·0
Lead	Pb	207·20
Lithium	Li	6·94
Lutecium	Lu	175·0
Magnesium	Mg	24·32
Manganese	Mn	54·93
Mercury	Hg	200·6
Molybdenum	Mo	96·0
Neodymium	Nd	144·3
Neon	Ne	20·2
Nickel	Ni	58·68
Niton (radium emanation)	Nt	222·4
Nitrogen	N	14·01
Osmium	Os	190·9
Oxygen	O	16·0
Palladium	Pd	106·7
Phosphorus	P	31·04
Platinum	Pt	195·2
Potassium	K	39·10
Praseodymium	Pr	140·9
Radium	Ra	226·0
Rhodium	Rh	102·9
Rubidium	Rb	85·45
Ruthenium	Ru	101·7
Samarium	Sa	150·4
Scandium	Sc	44·1
Selenium	Se	79·2
Silicon	Si	28·3
Silver	Ag	107·88
Sodium	Na	23·00
Strontium	Sr	87·63
Sulphur	S	32·06
Tantalum	Ta	181·5
Tellurium	Te	127·5
Terbium	Tb	159·2
Thallium	Tl	204·0
Thorium	Th	232·4
Thulium	Tm	168·5
Tin	Sn	118·7
Titanium	Ti	48·1
Tungsten	W	184·0
Uranium	U	238·2
Vanadium	V	51·0
Xenon	Xe	130·2
Ytterbium (Neoytterbium)	Yb	173·5
Yttrium	Yt	88·7
Zinc	Zn	65·37
Zirconium	Zr	90·6

Atoms—See pages 10 and 22.

Attraction—See page 10.

Barium and its Compounds—See page 74.

Barometer—See page 55.

Barytes (**Heavy Spar**)—See Barium.

Basalt—A dark-coloured form of Felspar. (See Felspar.)

Bases—See page 25.

Bath Stone—A natural formation of stone chiefly composed of calcium carbonate and much used for buildings.

Batteries (Electrical)—See page 46.

Batteries (Storage)—See page 51.

Bauxite—Hydrated oxide of aluminium. (See page 71.)

Beer—Infusion of malt, flavoured with the bitter of hops and fermented with yeast.

Beet-Sugar ($C_{12}H_{22}O_{11}$)—Sugar extracted from beetroots, which contain from 14 to 18 per cent. of cane-sugar.

Benzene (C_6H_6)—Is a liquid hydrocarbon obtained from the destructive distillation of coal, being contained in that part of the coal-tar which boils over at from 80° to 85° C. It can be obtained in a crystalline state by freezing; is an excellent solvent for resins and fats, is largely used as a fuel for motors and as a primary material in the production of aniline colours and many other carbon compounds.

Benzol—Commercial benzene.

Beryl—A mineral consisting of silicate of aluminium and glucinum.

Bismuth and its Compounds—See page 74.

Bitumen—A soft deposit, in the nature of hydrocarbons of complicated composition, often found associated with petroleum, as, for example, at Trinidad, and largely used for paving and other purposes.

Black-damp.—See page 69.

Blacklead—See page 66.

Bleaching—See pages 40 and 104.

Bleaching Powder—See pages 76 and 78 ; also Alkali Trade.

Blende—See page 107.

Blue Vitriol—A common name for copper sulphate. (See Copper.)

Boiling-Point—Is the temperature at which a liquid is converted into vapour at the standard pressure of 760 mm. of mercury. (See page 42.)

Bone Ash—See page 93.

Bone Black—A form of carbon or charcoal prepared by burning bones and afterwards dissolving out the mineral parts. (See page 66.)

Bone Meal—See page 93.

Boracic Acid—See page 75.

Borax—See page 75.

Boron and its Compounds—See page 75.

Brandy—Is, in the main, real spirits of wine prepared by distillation of fermented wines and coloured with burnt sugar.

Brass—See pages 32 and 107.

Britannia Metal—See pages 73 and 106.

Bromides—See page 29.

Bromine and its Salts—See page 75.

Bronze—See pages 81 and 106.

Cadmium—See page 75.

Caffeine—The alkaloidal principle of coffee and tea.

Calamine—See page 107.

Calcium and its Compounds—See page 76.

Calcium Carbide—See page 77.

Calcium Phosphide—See page 94.

Calcspar—See page 76.

Caliche—See pages 58, 84, 95, 98, and 100.

Calomel—See page 89.

Camphor ($C_{10}H_{16}O$)—Is a well-known natural product of characteristic odour formed in camphor-trees which grow in China, Formosa and Japan, and is obtained by distillation of the wood and all parts of the trees. It is accompanied by oil of camphor, a hydrocarbon allied in composition with turpentine. Camphor is largely used in the arts and industries, also as a vermifuge and in medicine.

Capillary Attraction—Is an attraction resulting from the adhesion or cohesion of fluids to solids. The melted wax of a night-light or candle flows to the burning wick by capillarity, and water is supplied to the roots and stems of growing plants by the same force.

Canada Balsam—A crude turpentine extracted from the *Pinus balsamea* or Balm of Gilead Fir.

Caoutchouc—Another name for India-rubber.

Carbolic Acid, C_6H_6O (or Phenol)—A white crystallizable substance, of considerable antiseptic character and characteristic odour, obtained from coal-tar.

Carbon—See pages 15 and 65.

Carbonates—See page 69.

Carbon Compounds—See pages 65 to 70.

Carbon Disulphide—See pages 69 and 104.

Carbon Oxides—See page 68.

Carbonic Acid—See page 69.

Carborundum—A compound of carbon with silicon, largely used, by reason of its great hardness, for grinding and cutting metals in engineering shops. (See page 52.)

Carnallite—See page 95.

Castor Oil—An oil extracted from the seeds of the castor oil plant (*Ricinus communis*) used as a lubricant, also in medicine and soap-making.

Catalytic—Is the name given to a remarkable property which is exhibited by certain substances in initiating or exhilarating chemical action between two or more other chemical substances. For example, platinum in a spongy condition promotes the combination of hydrogen and oxygen gases to form water; a little of this so-called *platinum black*, when thrown into a mixture of the two gases, causes them to combine with a loud explosion. It also causes the ignition of coal-gas in presence of air. The use of nickel in the hydrogenation of oils, as referred to in the text, is another act of catalysis. (See pages 62 and 78.)

Cellulose ($C_6H_{10}O_5$)—The structural tissue forming the walls or skeletons of plants, convertible into sugar, gun-cotton, nitro-cellulose, collodion, artificial silk, etc. Cotton contains about 90 per cent. of cellulose, and the proportion in woods of various sorts ranges from about 40 to over 60 per cent.

Cellulose is soluble in an ammoniacal solution of cupric oxide, and this solution readily dissolves cotton and linen fibres. Advantage of this fact is taken in the manufacture of so-called "Willesden paper." There is now a large industry in the manufacture of so-called artificial silk, which is also made from cellulose.

Cement (Portland Cement)—Is prepared from clay and chalk which are ground together in water, and after allowing the mixture to settle, the water is poured off and the deposit is calcined (intensely heated). It is then ground dry ready for use. When mixed with a small proportion of water, it forms a very hard and tenacious cement which expands as it solidifies or "sets," and—unlike ordinary mortar—can be used for hydraulic purposes.

Cerium—See page 77.
Chalybeate (Waters)—containing iron in solution.
Charcoal—See page 66.
Chemical Affinity—See page 10.
  Attraction—See page 10.
  Changes—See pages 9, 35, and 40.
  Combination—See pages 7, 10, and 12.
  Compounds—See page 17.
  Decomposition—See page 8.
  Elements—See pages 1, 11, 13 to 15, and 113.
  Elements and their Compounds—See pages 53 to 108
  Equations—See pages 15 to 22.
  Interactions—See page 15.
  Nomenclature—See page 30.
  Reactions—See page 15.
  Symbols—See page 13.
  Synthesis—See page 9.
  Valencies—See page 23.
Chemistry (Definition of)—See page 2.
Chile Nitre—See pages 58, 84, 95, 98, and 100.

China (Porcelain, Pottery, Stoneware, etc.)—These articles are made from various classes of minerals, such as China clay, a product resulting from the gradual decomposition of rocks (including *felspar* and *granite*) in the nature of silicates. (See Clay.)

Chloride of Lime—See pages 76 and 78; also Alkali Trade.

Chlorides—See pages 29 and 79.

Chlorine and its Compounds—See pages 39 and 77. (See also Alkali Trade Chart.)

Chloroform ($CHCl_3$)—Is a valuable volatile anæsthetic, prepared from alcohol by the action of bleaching powder and water. It is also a useful solvent of fats and other substances.

Choke Damp—See page 69.

Chlorophyll—See page 40.

Chromium and its Compounds—See page 80,

Chrome Green—See page 80.

Chrome Yellow—See page 80.

Cider—Fermented juice of apples.

Cinnabar—See pages 90 and 102.

Clay—A natural compound of alumina and silica (silicate of alumina) resulting from the combined action of air and water upon certain rocks. (See pages 71 and 97.)

China clay, as mined in Cornwall, is chiefly produced by the disintegration of the rock known as *pegmatite*—a kind of granite—and is much used in making pottery and stoneware. Porcelain is made non-porous by glazing.

Pipeclay, another variety, is largely used in making clay tobacco-pipes.

Fireclay, as used to make fire-bricks, is a natural mixture of *kaolin* or china clay mixed with sand as found beneath certain coal-beds, and is almost infusible. The fireclay is moulded into brick form and then burned at a very high temperature. (See also page 97.)

Coal—See pages 67 and 70.

Cobalt—See page 80.

Cocoa-nut Oil—A natural oil extracted from the kernels of cocoa-nuts, much used in making margarine (butter substitute).

Cohere—To cohere or stick.

Coinage—See pages 83, 92, and 99.

Collodion—Is a solution of gun-cotton in ether and alcohol, largely used in photography.

Colloid—Jelly-like and not crystallizable. (See Dialysis, also pages 3 and 29.)

Colophony—Another name for common rosin obtained from crude American turpentine.

Colorimeter—An instrument for making a comparison between the colours or depth of tint of a column of liquid with that of a prepared standard solution.

Combining Proportions—See page 10.

Combustion—See pages 4, 37, 44, 54, and 68.

Component—A part of a substance.

Compounds—See page 17.

Compressed—Pressed or squeezed together to occupy less space.

Concave—A gentle hollowing in from the centre to the sides.

Concentrate—To strengthen a solution, as, for example, by evaporation. (See page 6.)

Constituent—One ingredient of a substance.

Convex—A gentle swelling out from the sides to the centre.

Copper and its Compounds—See page 80.

Coral—See page 76.

Corrosive Sublimate—See page 90.

Corundum—See page 72.

Cotton-Seed Oil—A natural oil extracted from cotton seed and much used in soap-making.

Cream of Tartar—A tartrate of potassium used in medicine and the dyeing industry.

Creosote—A product of the distillation of coal-tar; of mixed composition. (See also page 71.)

Cryolite—See pages 72 and 82.

Crystals—Substances of symmetrical or geometrical forms—the reverse of amorphous. (See pages 3, 28, 38, and 68.)

Cyanogen (CN)—A very poisonous gas with an odour reminding of bitter almonds, and best known in combination with potassium as potassium cyanide. (See Potassium.)

Decantation—Pouring off a liquid from a sediment or deposit.

Decomposition—See page 8.

Deflagration—A rapid combustion with evolution of light and heat.

Deliquescence—Absorption by certain solid substances of moisture from the air, whereby they become more or less liquid in character; common salt, for example, is deliquescent. (See page 4.)

Dense—Heavy, thick.

Density—Relative weight compared with a standard weight. Water is taken as the standard for liquids and solids. For densities of gases see page 23.

Desiccate—To denude or rob of water—to dry.

Dew-point—See Humidity.

Dextrine—See Starch.

Dextrose—See Starch.

Dialysis—Is a sort of diffusion by means of which a liquid which contains, say, a mixture of a substance which is crystallizable, such as salt or sugar, and another (colloid) which is not crystallizable, such as albumen or gum, can be separated. This is effected by placing the mixture in a tray or other vessel having as its bottom a sheet of parchment paper or animal membrane, such as bladder, etc., and floating or suspending this vessel in a dish of water, when the crystallizable substance in solution dialyzes or diffuses through the parchment dialyzer into the water outside, and the colloidal substance in solution remains behind in the containing vessel. (See page 29.)

Diamond—See page 66.

Diastase—An active principle contained in extract of malt, capable of turning starch into dextrine and sugar. (See also Enzymes.)

Diffusion—Widely spreading or extending; capability of mixing together as regards gases. (See page 6.)

Digest—To steep in or expose a substance to the solvent action of a fluid.

Dilute—Weak in strength. (See page 5.)

Disinfectant—A preparation that destroys in any way the infectants or causes of disease or renders them innocuous.

Dissociation—Is the term given to spontaneous or forced acts of decomposition. Ordinary carbonate of ammonia on exposure to the air breaks up or is dissociated into bicarbonate of ammonium and ammonia. Similarly, when steam is strongly heated, it is forcibly dissociated into oxygen and hydrogen. (See page 45.)

Dissolve—The act by which a substance goes into solution, as when salt is dissolved in water, or oil in alcohol. (See page 5.)

Distillation—The act of converting a substance into vapour and then condensing same. (See pages 3, 41, and 64.)

Dolomite—A mineral consisting of a double carbonate of calcium and magnesium. (See page 89.)

Ductility—Capability of being drawn into wire. (See page 32.)

Dynamite—An explosive compound prepared from nitro-glycerine. (See Explosives.)

Dynamos—See page 50.

Ebonite or Vulcanite. (See Vulcanite; also Sulphur.)

Ebullition—The act of boiling.

Effervescence—Escape of gas, as when, for example, an acid reacts on marble, or from soda-water when liberated from a siphon. (See pages 2 and 15.)

Efflorescence—Salts which give up or lose a part of their water of crystallization on exposure to the air are described as efflorescent.

Common washing soda ($Na_2CO_3 10H_2O$) by efflorescence loses 9 out of its 10 molecules of water and becomes reduced to the carbonate of sodium represented by the formula Na_2CO_3,H_2O. (See page 4.)

Electricity—See page 45.

Electric Batteries—See page 46.

Furnace—See pages 52 and 71.

Lamps—See page 51.

Light—See page 51.

Motors—See page 50.

Radiators—See page 41.

Telegraph—See page 50.

Telephone—See page 51.

Electrode—The pole of an electric battery.

Electrolysis—Decomposition of fluids by the agency of the electric or voltaic current. (See page 48.)

Electrolyte—The body or substance broken up by electrolysis.

Electro-Gilding—See page 83.

Electro-Plating—See page 48.

Elements—See pages 1, 11, and 13 to 15.

Emerald—A double silicate of aluminium and glucinum found in mineral form.

Emery—A native form of alumina coloured with oxides of iron and manganese; used for grinding and polishing by reason of its hardness.

Emulsion—A mechanical admixture of fluids that will not naturally mix together, such as oil and water. Emulsions separate more or less on standing into layers.

Energy—The power of doing work. (See page 34.)

Enzymes—Colloidal nitrogenous substances contained in living animal and vegetable tissues, of which Diastase is illustrative. (See Diastase and Ferments.)

Epsom Salts (Sulphate of Magnesium, $MgSO_4$)—See page 89.

Equations—See page 15.

Essential Oils—Are the volatile oils or essences formed naturally in various trees and plants, such as oil of turpentine (pine-trees), eucalyptus oil (eucalyptus-trees), camphor oil (camphor-trees), etc.

Etching—See page 82.

Ether, $(C_2H_5)_2O$—A volatile substance produced from alcohol by the action of strong sulphuric acid. It is largely used as an anæsthetic and is a useful solvent of many organic substances, including fats and oils.

Ethereal—Nature of ether—light, volatile.

Evaporation—The passage from the liquid to the vaporous state, as when water is evaporated by heat into steam. (See page 6.)

Exhalation—The act of exhaling or passing out of vapours, as in the act of breathing out.

Expansion—The act of occupying a greater space. Gases are easily expanded by heat.

Explosives—Gunpowder (see pages 7 and 96) is a so-called "low explosive," while the "high explosives" have a velocity of explosion some 500 times greater. These high explosives are rich in nitrogen, and when detonated furnish large quantities of that gas and others which are enormously expanded by the heat generated by the chemical changes which take place, so that they amount to from 10,000 to 15,000 times the volume of the explosive substance itself.

Just as nitre supplies the oxygen necessary to burn the charcoal and sulphur contained in gunpowder, so (by chemical means) hydrogen is removed from cotton (cellulose), glycerine, phenol, toluene, etc., and is substituted by groups of the molecule NO_2, which contains and supplies the oxygen essential to the combustion of the associated carbon and hydrogen, the carbon being converted into gaseous oxides and the hydrogen into steam, while at the same time the nitrogen is also set free in the form of gas. Some of these substances, and their nitrated forms, may be roughly indicated as follows:

Cellulose ($C_6H_{10}O_5$) is chemically changed into nitrated cellulose ($C_6H_7(NO_3)_3O_2$).

Glycerine ($C_3H_8O_3$) becomes changed to $C_3H_5(NO_3)_3$.

Phenol (C_6H_6O) becomes changed to $C_6H_2(NO_2)_3OH$.

Toluol, or toluene, (C_7H_8), becomes changed to $C_7H_5(NO_2)_3$ (Tilden) or $C_7H_3(NO_2)_3$ (Smith).

Nitro-glycerine is a heavy body of oily consistency, obtained by the action of strong nitric acid upon glycerine. (See Glycerine.)

Dynamite, so largely used for blasting purposes in mines and otherwise, is a mixture of nitro-glycerine and the infusorial earth named Kieselguhr (see Silica). *Picric acid*, or tri-nitro-phenol, $C_6H_2(NO_2)_3OH$, is obtained by the graduated action of strong nitric acid upon phenol (carbolic acid), and is itself an explosive. Various mixtures of it with *collodion*—a nitrated cellulose prepared from gun-cotton by dissolving it in mixtures of ether, alcohol, and other bodies—in compressed and molten forms constitute the explosives "*melinite*" and "*lyddite*."

Gun-cotton, or tri-nitro-cellulose, is obtained by the graduated action of nitric acid upon cellulose, and smokeless gunpowders and most of the violent propellants contain gun-cotton.

Cordite is the chief military propellant, and is a mixture of gun-cotton and nitro-glycerine dissolved in acetone and thickened and rendered more stable with about 5 per cent. of vaseline. The excess of acetone is afterwards evaporated off from the gelatinous mass, which is prepared in cord form.

Gelignite is a mixture of nitro-glycerine, nitro-cellulose, wood-pulp, and potassium nitrate (KNO_3).

Tri-nitro-toluol (T.N.T.) is obtained by the graduated action of strong nitric acid upon toluol, or toluene (a derivative of benzene obtained from coal-tar), in the form of yellow prismatic crystals melting at 80° C., and has replaced picric acid to a large extent as a filling for shells, being more stable in character and cheaper. (See also Ammonium Nitrate, p. 59.)

Extraction—Taking or drawing out—a solvent action; for example, water will extract sugar from a mixture of it with an insoluble substance like sand.

Fats—Compounds of fatty acids and glycerine, such as tallow, suet and oils. (See Sodium ; also Glycerine.)

Felspars—Compound silicates of aluminium and other metals, found abundantly in nature as minerals.

Fermentation—A chemical change induced by an enzyme or a ferment such as yeast. For example, sugar when fermented by yeast produces alcohol. Many low forms of life, such as bacteria, can induce fermentative changes in various substances. Beer, wine, alcohol, vinegar, and many cheeses are fermented products.

Ferruginous—Containing iron.

Filter—To pass through a strainer, an operation often resorted to by chemists to separate solid matters from liquid matters.

Filtrate—The liquid that passes through a filter.

Fire-Damp—An explosive gas, chiefly composed of methane (CH_4), naturally produced from coal in coal-mines. (See also page 68.)

Fireworks—See page 102.

Flint—See page 97.

Flame—See pages 4, 17, and 38.

Fluorescence—The property of producing opalescent colour or bloom different from that of the liquid or substance which causes it. Green crystals of fluorspar give blue reflection, and sulphate of quinine solution exhibits the property in a marked degree.

Fluorine—See page 82.

Fluorspar—See pages 76 and 82.

Focus—The point at which rays of light come together after passing through a convex lens.

Force—See pages 10 and 34.

Formulæ—See page 13.

Fractional Distillation—Affords the means of separating the various constituents of distillable liquids, by collecting the several portions which pass over at varying temperatures; for example, alcohol boils at 78° C., aniline boils at 185° C., and can be separated by this process.

Fuller's Earth—A natural porous silicate of alumina and a powerful absorbent of oily matters.

Fumigation—Exposing to the action of vapours or fumes.

Fusel Oil—A residue from the distillation of alcohol as produced by fermentation.

Fusion—The liquidation or melting into the fluid state of solids by means of heat. (See page 43.)

Galena—See pages 87 and 102.

Galvanism—See Electricity.

Garnierite—A hydrated silicate of nickel and magnesium.

Gases (Diffusion of)—See page 6.
(Liquefaction of)—See pages 44 and 57.
(Volumes of)—See page 21.

Gelatin—Is an albuminous substance forming an important constituent of many animal tissues including bones and horn. Commercially, it may be prepared from bones by digesting them in water acidified with hydrochloric acid, which assists in the separation of the gelatinous parts from the calcareous parts. In the dry state it is almost colourless or has a slightly yellowish tint. It swells when placed in water and becomes translucent, but does not dissolve to any great extent, although it passes into solution upon heating. Gelatin as prepared from various sources differs slightly in composition, but contains approximately 50 per cent.

of carbon, 6·5 to 7 per cent. hydrogen, and from 17·5 to 18 per cent. nitrogen.

Gelatin is largely employed in the preparation of jellies and for other purposes.

German Silver—See page 32.

Germicide—A preparation that kills germs (bacteria, etc.).

Glass—See page 98.

Glauber's Salts (Sulphate of Sodium, Na_2SO_4). (See Sodium.)

Glucose ($C_6H_{12}O_6,H_2O$) (or Inverted Sugar)—An uncrystallizable sugar produced from sugar, dextrine, starch and cellulose by the action of dilute acids and ferments.

Glue—Is made from the parings of hides, hoofs, horns, and other animal offal by boiling them in water. The liquid thus prepared is afterwards poured into frames or moulds, wherein it sets in a solid state.

Glycerine ($C_3H_8O_3$)—Is a syrupy, colourless and odourless liquid of a somewhat sweet taste, which solidifies to a crystalline condition when exposed to a sufficiently low temperature. It is a product of the decomposition (saponification) of fats and many oils, and is practically manufactured on a large scale from the spent lyes resulting from soap-making. The soda used for soap-making combines with the fatty acids, while the glycerine passes into solution and is recovered from the lyes.

Glycerine is also produced in large quantity by distilling fats in superheated steam, by which they are broken up into fatty acids and glycerine. It is largely used in the preparation of nitro-glycerine and other explosives. (See also Explosives, and Sodium.)

Gneiss—A mineral of granite character containing mica.

Gold and its Compounds—See page 82.

Graphite—See page 66.

Gravitation—See page 37.

Greenockite—See page 75.

Green Vitriol or Copperas—Common names for Ferrous Sulphate. (See Iron.)

Guano—Excrement of sea-fowl, used as manure, consisting largely of phosphate of lime.

Gums—Is the name given to a number of vegetable products, all more or less of a sticky character, and belonging in the main to the class of compounds known as carbohydrates.

Gum Arabic is the dried juice from the bark of various species of Acaciaæ which flourish in Arabia, Egypt and Senegambia. It dissolves slowly in water and is well known and used as gum solution for sticking purposes, also in the making of pharmaceutical and other emulsions.

Copal Gum is a resinous gum which flows from certain trees in Central South America (*Elæcarpus copallifera* and *Rhis copallinum*), and is of great value in the making of varnishes.

Gum Senegal is another that is used in varnish-making, and comes from near the River Senegal, in Africa.

Gum Thus—See Turpentine.

Gum Tragacanth is the gum of the cherry-tree and is much used by pharmacists in making emulsions.

Gun-Cotton—An explosive compound formed by the action of nitric acid upon cotton or cellulose. (See Explosives.)

Gun-Metal—See page 81.

Gunpowder—See pages 7 and 96. (See also Potassium and Explosives.)

Gutta-percha—A natural dark gum, prepared from the juice of gutta-percha-trees grown in Brazil, Malay and other tropical places. It is soft and impressionable when heated in hot water, and is used for insulating cables and electric wires (by covering), also for making golf-balls and many other purposes.

Hæmatite—See page 85.

Halogen—A name given to the group of elements including chlorine, iodine, bromine, and fluorine, because with metals they form compounds analogous to sea-salt. (See page 14.)

Hartshorn—A common name for crude ammonium carbonate, originally obtained by distillation of horn shavings.

Heat—See pages 17 and 40.

Heavy Spar—See pages 74 and 103.

Helium—See page 84. (See also Radium.)

Homologue—A body having a relative or corresponding position in a series of analogous substances.

Humidity of the Air—The moisture present therein, and the Dew-point is the temperature at which air is saturated with moisture. (See page 53).

Humus—Decayed vegetable matter as found present in the soil.

Hydrates—See page 26.

Hydrochloric Acid—See page 79 ; also Alkali Trade Chart.

Hydrocyanic or Prussic Acid (HCN)—A colourless liquid of peculiar odour like bitter almonds and very poisonous, nearly related in a chemical sense to cyanogen. (See page 70.)

Hydrofluoric Acid—See Fluorine.

Hydrogen—See page 60.

Hydrogen Dioxide—See page 65.

Hydrogenation (of Oils)—See page 61.

Hydrometer—An instrument designed to ascertain the relative weights or densities of fluids as indicated by measurements on the stem of the instrument when floated vertically in the liquids to be examined.

Sike's hydrometer is used by Excise officers to determine the alcoholic strength of spirituous liquors.

Hydroxides—See page 26.

Hygrometer—See page 53.

Hygroscopic—The property of absorbing moisture from the air. This is not limited to solids; sea-water, for example, is capable of absorbing moisture from the air when saturated with it at the same temperature.

Ice—See page 41.

Iceland Spar—A native carbonate of calcium.

Ignition—To set on fire or to take light. A piece of wood ignites on applying a lighted match. A jet of gas takes light in the same way, and both the wood and gas are thus ignited or burned with production of light and heat.

Impervious—Not admitting passage.

Incandescent—A state of heat at which a substance begins to give out light or to glow. (See pages 38 and 51.)

India-Rubber—An elastic compound found in the juice of certain plants which grow in tropical zones. (See Rubber.)

Indigo ($C_{16}H_{10}N_2O_2$) — A blue colouring matter prepared from the plant *Indigofera tinctoria* and formed from indican which exists in its juice and that of some other plants. It is now made synthetically.

Induction—The power which one body exhibits of inducing a corresponding state in another body, as when a rotating magnet acts in the dynamo. (See page 50.)

Inflammable—See page 10.

Infusing—Steeping in or exposure of a substance to the solvent action of a liquid.

Inhalation—The act of inhaling or breathing in through the mouth and nose.

Inorganic Compounds—See page 70.

Insoluble—Incapable of being dissolved; for example, sand is insoluble in water.

Insulate—To detach or place out of communication.

Interactions—See page 15.

Iodides—See page 29.

Iodine—See pages 29 and 84.

Iron and its Compounds—See page 85.

Ironstone—See Iron.

Isinglass—A white form of gelatine, made from the bladders of sturgeons and used for clarifying beer, etc.

Isomerism—Substances composed of the same number of the same atoms but differing in molecular arrangement and properties are described as isomeric.

For instance, terpenes (formula $C_{10}H_{16}$), being the hydrocarbons forming the chief ingredients of many essential oils, such as the oils of turpentine, lemon, orange and bergamot, have all the same percentage composition, but they differ largely in their physical and chemical properties, and are described as isomers. In other words, there is a family resemblance, but the internal structure or atomic building up of their molecules is not uniform.

Jasper—See page 97.

Kainite—See page 95.
Kaolin—A peculiar variety of clay. (See Clay.)
Kelp—See page 84.
Kieselguhr—See page 97.

Lacquer—Varnish consisting of shellac dissolved in alcohol and coloured as desired.
Lactose, or Milk-Sugar ($C_{12}H_{22}O_{11}$)—A sugar or carbohydrate which occurs naturally in the milk of mammalia.
Lamp-Black—The black carbonaceous deposit which results from the imperfect burning of lamp and other oils and fatty bodies. The blackening of the glass of a paraffin lamp is due to the deposition of lamp-black. (See page 66.)
Lapis Lazuli—A native silicate of alumina from which ultramarine was at one time prepared.
Lead and its Compounds—See page 87.
Leather—Prepared from animal hides by the action of tannins, the process being described as *tanning*.
Lenses—Concave and convex glasses that lessen or enlarge objects which are looked at through them respectively.
Light—See page 37.
Lightning—See page 45.
Lignite—A natural deposit allied to coal which yields so-called paraffin oils upon distillation.

Lime—See page 76.

Limelight—See page 38.

Limestone—See page 76.

Limpid—Clear and transparent fluids, the particles of which exhibit great mobility or rapidity of movement.

Linseed Oil—Is expressed by pressure from flax-seed, and is largely used in making paints and soaps, while the residual cake is used for feeding cattle.

Litharge—See Lead.

Lithium—See page 88.

Litmus—See page 25.

Loadstone—See pages 49 and 85.

Locomotives—See page 43.

Lunar Caustic—See page 99.

Macerate—To digest—a process often used for extracting the soluble parts of plants and herbs, etc.

Madder—A colouring matter (Turkey-red, or alizarin) made from the roots of a plant cultivated in France and Holland. Used for dyeing purposes—orange, purple, and yellow.

Magma—A thin paste.

Magnesite—See page 89.

Magnesium—See page 89.

Magnet—See page 7.

Magnetism—See pages 45 and 49.

Malachite $(CuCO_3, Cu(HO)_2)$—See page 81.

Malleability—Capability of being hammered out into thin sheets. (See page 32.)

Malt—Is barley or other grain, the starch of which has been converted into sugar by germination in the process known as malting.

Manganese and its Compounds—See page 89.

Marble—See page 76.

Marking Ink is prepared from nitrate of silver and gum coloured with Indian ink.

Mastic or Gum Mastic is a native form of bitumen.

Matches—See pages 4, 16, and 36.

Matter—See pages 1 to 5, 20, and 35.

Measures—See page 20.

Meerschaum (or Sea-foam)—Is a very light deposit of a hydrated silicate of magnesium found in certain alluvial deposits in Asia Minor, Greece and elsewhere. It is, as a rule, slightly yellow in colour and finds utilization in the making of pipe-bowls and other articles.

Melting Points—See page 43.

Menstruum—A solvent or liquid that can be used for extracting the soluble parts of a solid substance.

Mercury—See page 90.

Metallurgy—The art of working in metals.

Metals—Substances of peculiar lustre and good conductors of heat and electricity, embracing many of the elements. (See also pages 13, 14, and 32.)

Methylated Spirit—A mixture of alcohol with 10 per cent. of common wood-spirit, tainted with other substances to render it unfit for consumption.

Mica—Is the general name given to a number of minerals, including *muscovite*, having a more or less laminated or so-called *micaceous* character. For the most part they are silicates of magnesium and potassium, but they are of complicated composition and vary considerably. Its uses in the arts are similar to those of talc.

Microcosmic Salt—A compound phosphate of sodium and ammonium ($NaNH_4HPO_4,4H_2O$).

Microscope—An instrument arranged so as to magnify the objects looked at through it. When it has only one lens it is known as a simple microscope, but when it has two or more it is a compound microscope.

Milk-Sugar—See Lactose.

Milk of Sulphur—See page 104.

Minerals—Rocks and other inorganic materials.

Miscible—See page 6.

Mixtures—See pages 1 and 7.

Molecular Weights—See page 21.

Molecules—See pages 10 and 22.

Molybdenum—See page 91.

Monazite Sand—See page 105.

Mordant—A chemical agent used for fixing colours in dyeing and calico-printing, the colouring matter being thereby securely held in the fibres of the material by a chemical substance either coagulated or precipitated in contact therewith, thus producing so-called *lakes*.

Morphine ($C_{17}H_{19}NO_3$)—See Opium.

Mortar—Is a mixture made of burnt lime slaked with water to a thin cream and sharp sand, and the hardening or setting which occurs when it is used for joining bricks together, etc., results partly from drying and partly from absorption of carbon dioxide from the air turning the lime into calcium carbonate—

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O.$$

Muriatic Acid—An old name for hydrochloric acid. (See page 79.)

Muntz Metal—See page 81.

Naphtha—A light oil-like body produced in the distillation of coal and used for illuminating purposes. There is also a mineral naphtha found naturally associated with bitumen and asphalt in many places.

Naphthaline ($C_{10}H_8$)—A white crystalline hydrocarbon of peculiar tarry odour, extracted from coal-tar, largely used as a moth preventive and carried by natives in India and the Far East as a fever preventive, on account of its antiseptic properties.

Nascent—Indicates the state of chemical substances at the moment of their generation or production, and in this state they are often more active in their properties than ordinarily.

Natron—A crude native form of a carbonate of sodium.

Neutralization—See page 27.

Nickel—See page 91.

Nicotine—Is the acrid principle of tobacco belonging to the class of substances known as alkaloids, and is a compound of carbon, hydrogen and nitrogen ($C_{10}H_{14}N_2$). As prepared in a crude form from tobacco, it is largely used as an insecticide for horticultural purposes and also for sheep-dipping (destruction of ticks and other pests on the wool of sheep).

Nitrates (in soil)—See page 60.

Nitre—See pages 58, 60, and 96.

Nitric Acid—See pages 60 and 104.

Nitrogen—See pages 57 and 58.

Nitrogen Trichloride—See page 36.

Nitrohydrochloric Acid—See Aqua Regia.

Nordhausen Acid—A concentrated form of sulphuric acid, originally prepared at Nordhausen in Saxony.

Occlusion—In a strongly heated condition some metals are not only permeable by gases, but have the property of absorbing or *occluding* them, as this is termed. At a red heat platinum occludes hydrogen gas. Iron will take up hydrogen also, and melted silver absorbs oxygen gas. (See Palladium.)

Oils—Liquid greasy substances in the nature of fats. (See Fats.)

Oils (Hydrogenation of)—See page 61.

Oleic Acid ($C_{18}H_{34}O_2$)—A fatty acid derived from many natural fats and fatty oils, largely used in soap-making.

Olein—Oily body found present in many natural fats, and which yields oleic acid (a fatty acid) and glycerine upon decomposition.

Olive Oil—An oil expressed from the fruit of the olive-tree (*Olea Europeæ*), much grown in Southern Europe, and which is of great value for many purposes, particularly as a food and in the manufacture of certain kinds of soaps.

Onyx or Calcedony—A native coloured form of nearly pure silica.

Opaque—Not transparent.

Opium—Is the dried juice extracted from the seed vessels of a poppy (*Papaver somniferum*), and contains amongst other substances several alkaloids, including about 10 per cent. of morphine ($C_{17}H_{19}NO_3$)—a powerful drug used largely in medicine as a soporific (sleep producer)—and narcotine ($C_{22}H_{23}NO_7$).

Ores—Compounds of metals as found in nature.

Organic Matter—See pages 15 and 65 to 70.

Organized—Arranged in definite form or structure, such as cells, fibres, membranes, hair, skin, etc.

Orpiment—See page 73.

Oxides—See page 29.

Oxidizing Agents—Chemical substances which are capable of giving up oxygen to other substances having an affinity for it.

Oxygen—See pages 53 and 56.

Oxy-Hydrogen Flame—Produced by burning a mixture of oxygen and hydrogen gases ; until superseded by the electric furnace it was used, amongst other purposes, in the manufacture of artificial rubies and sapphires. Its temperature is in the neighbourhood of 2,800° C. (See pages 38 and 42.)

Ozokerit—Is a wax occurring in the vicinity of coal in Moldavia and elsewhere. It is in the nature of a hydrocarbon and is used in connection with the manufacture of candles and other articles.

Ozone—See page 57.

Paints—Mixtures of white-lead or other heavy mineral bases with boiled linseed oil, oil of turpentine, and various pigments, used to prevent the rusting of iron and for the preservation of wood and other surfaces; also for artistic and decorative purposes. (See also Lead.)

Palladium—See page 92.

Palm Oil—Is obtained from the African oil-palm (*Elais Guinensis*) and other species of palms, and is much used in making candles, soap and margarine.

Paraffin—A general name given to a number of oily liquids in the nature of hydrocarbons used for illuminating purposes, and variously derived from the distillation of wood, coal, and shale, etc.

Peat—Is a deposit found naturally in fen and marshy areas, and results from chemical changes affecting the mossy and marshy plants which abound therein. Thus gradually accumulated, peat often forms beds of from some inches to many feet in thickness. When air-dried, peat forms a valuable fuel, and coked in ovens or when distilled (as is coal in the process of gas-making), it yields many valuable products allied in character to those derived from coal.

Percolate—To filter or pass through, as, when making drinking-coffee, the dry coffee is percolated by hot water.

Permanent White—See page 74.

Peroxide—Indicates an oxide of higher degree than the ordinary oxide. For example, barium oxide (BaO) is the ordinary oxide of barium, whereas the peroxide is BaO_2.

Peroxide of Hydrogen—See pages 19 and 65.

Perry—Fermented juice of pears.

Petroleum—An oil-like body of hydrocarbon character, produced in nature, and largely used, when refined, for illuminating purposes, also as a fuel both for heating and motor use.

Pewter—See page 106.

Phenol—See Carbolic Acid.

Phosphine—See page 94.

Phosphor Bronze—An alloy used as a substitute for bronze and gun-metal in gearings, bearings, wire ropes, etc., composed of copper and tin fluxed with a variable quantity of phosphorus, which is generally added in the form of phosphide of copper or phosphide of tin.

Phosphoretted Hydrogen—See pages 36 and 94.

Phosphorus—See pages 16, 38, and 92.

Photography—See pages 39 and 89.

Picric Acid ($C_6H_2(NO_2)_3OH$) (Tri-nitro-phenol)—A lemon-coloured crystalline substance largely used in the manufacture of explosives (see Explosives), and also as a yellow dye for silk and wool.

Pipeclay—A peculiar variety of clay found in Dorsetshire, used for making tobacco-pipes and certain kinds of pottery.

Pitchblende—See pages 96 and 106.

Plants—See page 39.

Plaster of Paris—See page 76.

Platinum—See page 94.

Plumbago—Another name for graphite or black-lead. (See page 66).

Polymeric—Substances having the same percentage composition but differing in molecular weight are said to be polymeric. For instance, ethylene (C_2H_4) and propylene (C_3H_6) are polymers. (See Isomerism.)

Porcelain—See Clay.

Porosity—See page 4.

Porphyry—A native form of felspar.

Potassium and its Compounds—See page 95.

Precipitate—To deposit or fall in the solid state out of a solution. For example, when a solution of chloride of sodium is added to a solution of nitrate of silver, the following interaction takes place:

$$NaCl + AgNO_3 = NaNO_3 + AgCl,$$

and the latter (chloride of silver), being insoluble, is thrown out of solution as a white precipitate.

Producer Gas—Is made by passing air over red-hot coke, thus generating a mixture of carbon dioxide (CO_2) and carbon monoxide (CO) with the nitrogen contained in the air used. It contains about 30 per cent. of carbon monoxide and is largely used on account of its cheapness for many purposes. (For examples, see pages 76 and 91.)

Proof-Spirit—Contains rather less than 50 per cent. alcohol.

Protyle. See page 1.

Prussian Blue—The name of a number of blue pigments being compounds of iron and cyanogen.

Prussic Acid—A common name for hydrocyanic acid (CNH).

Pumice-Stone—A porous molten rock found in volcanic areas, and probably derived from felspar.

Putty—A mixture of white lead and linseed oil.

Pyrites—See pages 80 and 102.

Pyrolusite—See page 89.

Pyrometer—Instrument for determining high temperatures, such as the fusing-points of metals and the heat of furnaces.

Quartz—See Silica.

Quicklime—See pages 4 and 76.

Quinine ($C_{20}H_{24}N_2O_2 + 3H_2O$)—Is one of the alkaloids extracted from the barks of certain species of *Cinchona*. It is intensely bitter in character, and the sulphate and chloride are both widely used as febrifuges and otherwise in medicine.

Radiation—Throwing out or dispersion, as, for example, the heat radiated from an open fire.

Radium—See page 96.

Rape Oil—Oil extracted from seed of the rape, a plant of the cabbage tribe of the genus *Brassica*.

Reactions—See page 15. (See also Interactions.)

Reagents—Chemical solutions used for testing purposes.

Realgar—See page 73.

Red-Lead—See Lead.

Reflection—A luminous ray projected upon a mirror is thrown back or reflected at an angle. (See page 39.)

Refraction—A luminous effect making a body partially immersed in water look as if it were broken.

Refrigerate—To make cool. There are processes for refrigerating perishable and other articles based upon the cooling which is produced by causing volatile liquids like strong ammonia and liquefied carbon dioxide to assume the vaporous state. This state of change involves the consumption or absorption, so to speak, of heat, and is used for cooling chambers in which foods, etc., are kept. Processes of refrigeration are often used in chemical investigations and operations. (See page 44.)

Respiration—See pages 54, 55, and 64.

Rock Crystal—See page 97.

Roman Cement—A modified form of hydraulic cement. (See Cement.)

Rosin—Is the gum that is left behind in the retorts when crude turpentine (as it exudes from the pine-trees which produce it, and known as *gum thus*), is distilled. It is very much used in various industries, and particularly for incorporation in soaps, having the property of combining with alkalies like fatty acids, and making a kind of soap.

When rosin itself is subjected to destructive distillation by greater heat, it is *cracked* or split up into a number of products, including rosin spirit and rosin oil, which pass over with the vapours and are condensed, whilst a pitch is left behind in the retorts.

Rouge—A common name for a prepared form of ferric oxide employed for polishing glass, etc.

Rubber—A well-known article extracted from the juice of rubber-trees, and much used in making motor and other tyres, overshoes, golf-balls and other articles.

Ruby—See page 71.

Saccharin—A synthetically prepared white crystalline organic substance about 300 times as sweet as cane-sugar.

Safety Lamps—As used by coal-miners to obviate explosions due to the accumulation of inflammable gases, are constructed on the known fact that a flame has difficulty in crossing or passing through wire gauze. This is due to the conductivity of the metallic gauze, which carries away the heat of the burning flame inside the lamp to such an extent that the explosive gas outside the lamp is kept below the temperature necessary for its ignition. (See page 68.)

Sal-ammoniac—An old name for ammonium chloride. (See page 59.)

Salt—See pages 77 and 99.

Salts—See pages 25 to 31.

Salt of Lemon—An acid oxalate of potassium.

Salt of Sorrel—Another name for the same substance.

Saltpetre—See page 96, also Nitre.

Sandstones—Siliceous stones more or less ferruginous in character, used for building purposes.

Sanitas Fluid—See page 65.

Sapphire—See page 71.

Saturation—The maximum degree to which a liquid can hold a solid in solution at any given temperature.

Many substances are more soluble in hot liquids than in cold ones, and such hot solutions as they cool down to the ordinary temperature throw down or can be caused to deposit the excess of the dissolved body. (See page 5.)

Sea-Water—See pages 63 and 77.

Selenium—See page 97.

Septic Poisons are chemical products produced by bacteria as in wounds.

Serpentine—A rock consisting of silicate of magnesium.

Shale Oil—Is a sort of petroleum oil distilled from shale or schist, as it is otherwise known, as found in the natural deposits of Scotland.

Shellac—A kind of rosin (prepared from insects known as *Coccus lacca*, which abound in the forests of Assam) much used in making varnishes and sealing-wax, etc.

Silica—See page 97. (See also Clay.)

Silicon—See page 97.

Silver—See page 99.

Slag—Or cinder from blast furnaces, containing as it does phosphates in considerable proportion, is, when reduced to powder, largely used as a phosphatic fertilizing material for agricultural purposes. (See Iron.)

Slag Wool.—See page 86.

Slaked Lime—See page 4; also Calcium.

Slate—Is a form of silicate of aluminium and magnesium as found in nature—a kind of argillaceous (clay-like) rock.

Smalt—See page 80.

Soaps—Combinations of fatty acids with alkali. (See Potassium and Sodium ; also Fats and Glycerine.)

Soapstone—Also known as *steatite* and French chalk, is a native form of silicate of magnesium.

Soda Nitre—See page 100.

Sodium and its Compounds—See page 99.

Solder—See Lead and Tin.

Solubilities (Salts)—See page 31.

Soluble—Admitting of being dissolved or passing into solution; for example, both sugar and salt are soluble in or dissolved by water.

Soluble Glass—See page 98.

Solution—See page 5.

Solvent—A liquid which will dissolve another substance; thus, water is a solvent of common salt.

Sound—See page 38.

Spectroscope—An instrument constructed of one or more prisms by which the coloured rays are separated when light is made to pass through them.

Spectrum—The band of colours into which white light can be broken up, as, for example, when passed through a prism.

Spelter—See page 107.

Sperm Oil—An oil extracted from the blubber of the sperm whale, and valuable for lubricating and burning.

Spirits of Wine—Alcohol of indefinite strength.

Spongy Platinum—See Catalytic.

Stalactites—Deposits of calcium carbonate like icicles, formed from dripping water in the roofs of caves by the escape of carbon dioxide from a solution of calcium carbonate dissolved in water and previously held in solution by its agency. (See Water, page 64.)

Stalagmites—Similar deposits growing up from the floor of caves.

Starch—Is found present in some of the parts of nearly all plants, and abundantly in the forms of wheat, barley, oats, arrowroot, rice, and the potato. Chemically it is a carbohydrate ($C_6H_{10}O_5$).

Potatoes contain on an average about 20 to 27 per cent. of starch; wheat from 50 to 75 per cent.

Sago is a starch produced from the sago-palm; tapioca is made from the *Jatropha Manihot;* and arrowroot is the starch of the tropical plant *Maranta arundinacea.*

Starch is not soluble in cold water, but when heated with water it swells up and assumes a more or less pasty condition, forming a kind of emulsion, commonly known in chemical laboratories as "starch solution," although but little passes into real solution.

If starch be heated in the dry state for some hours at a temperature of 200° C., its character becomes changed, and is then quite soluble in water, forming what is known commercially as British gum, as used by calico-printers for mixing with their colours. By the action of dilute acids and ferments, starch yields a number of sugar-like bodies known as dextrose, maltose, glucose, etc., which are largely employed in brewing and other industries, being substances which, like ordinary sugar, admit of being fermented into alcohol, which is the active (intoxicating) principle of beers.

Malt (see Malt) is largely employed in the manufacture of whisky, which is really spirit distilled from wort prepared from malt dried over a peat-fire.

Stassfurt Salts—See pages 77 and 95.

Steam—See page 43.

Steatite—Is a form of talc, and slabs of the mineral are often used for making firestones in furnaces and stoves.

Steel—See Iron.

Stockholm Tar—A tar distilled from the resinous wood of the pine, and largely used in connection with wooden shipbuilding for caulking.

Strontium—See page 102.

Strychnine ($C_{21}H_{22}N_2O_2$)—Is an exceedingly poisonous alkaloidal base extracted from *Strychnos nux vomica* and some other beans.

Stucco—A coloured form of plaster of Paris prepared with a solution of size.

Sublimation—A sort of dry distillation; volatilization of solid substances like camphor, iodine and sulphur, and the condensation of their vapours anew into solid form. (See pages 41 and 103.)

Sugar, or Cane-Sugar ($C_{12}H_{22}O_{11}$)—Is abundant in the stems of certain grasses, particularly in the sugar-cane, from which it is produced by pressure between rollers and subsequent purification. Also manufactured from beetroots. (See also Glucose.)

Sugar of Lead—Acetate of lead. (See page 35.)

Suint—Is a peculiar fatty body found present in sheep's wool. Besides fat, it contains also a quantity of potash. A fleece weighing 9 pounds contains about 20 ounces of suint, of which about one-third is potash. The fat is used for soap-making and in the preparation of lanoline. (See page 95.)

Sulphides—See page 29.

Sulphur—See page 102.

Sulphuretted Hydrogen—See page 104.

Sulphuric Acid—See pages 36 and 104.

Symbols—See pages 13, 21, and 113.

Sympathetic Ink—Prepared from chloride of cobalt; characters traced with it on paper become blue when heated and fade again on cooling.

Synthesis—See page 9.

Synthetize—To chemically build up or unite in regular structure or definite proportions. (See page 9.)

Talc—A compound silicate of magnesium of considerable utility for making stove-windows and gas-chimneys, being transparent and incombustible. (See Mica and Steatite.)

Tannins—Astringent principles of the bark and other parts of trees, such as the oak, which combine with albumin and gelatine as occurring in animal hides to form leather.

Tantalum—See page 105.

Tar—See page 71.

Tartar Emetic—See page 73.

Telescope—An instrument formed of several lenses so arranged as to magnify distant objects.

Temperatures—See page 42.

Tension (of Gases)—The force with which the particles or molecules tend to recede apart and to occupy a greater space.

Test Papers—Papers impregnated as, for example, with litmus. (See page 25.)

Theine—Identical with Caffeine. (See Caffeine.)

"Thermit" Process—When a mixture of metallic aluminium powder and ferric oxide is subjected to ignition by a fuse or otherwise, the whole mass becomes incandescent, the aluminium combining with the oxygen of the iron oxide, setting free the molten iron which forms a layer below. The temperature realized in this process is estimated at about 3,500° C., and being high enough to melt all known metals, the process is utilized, among other applications, for the repair of broken castings and joining up the ends of tramway rails without removal. For this latter purpose a mould is placed round the rail-ends in such wise as to receive a charge of the molten iron, the excess metal being afterwards cut away or otherwise removed as required.

Thermometers—Instruments used to ascertain or register degrees of heat. (See page 42.)

Thorium—See page 105.

Tin—See page 105.

Titanium—See page 106.

Topaz—An aluminous mineral containing fluorine.

Translucent—Pellucid, transparent, clear.

Transparent—Admitting the passage of light, easily seen through.

Treacle is for the most part uncrystallizable sugar obtained in the preparation of cane-sugar; also called molasses. It is used for sweetening purposes, and also in the preparation of rum by fermentation and distillation of the fermented product.

Tungsten—See page 106.

Turmeric—A yellow or saffron colouring-matter prepared from the roots of an East Indian plant (*Curcuma*), used for dyeing and in medicine.

Turpentine ($C_{10}H_{16}$)—Oil or spirits of turpentine is a mixture of so-called hydrocarbons—that is, *terpenes* or combinations of carbon and hydrogen—produced by nature in pine-trees. It is collected by making cuts or slits in the bark of the trees, through which there exudes *gum thus* or crude turpentine, and when this is distilled the oil or spirit of turpentine passes over as vapour and is afterwards condensed, leaving rosin behind. Turpentine is very largely used, chiefly in the preparation of paints and varnishes.

Turquoise—A native hydrated phosphate of aluminium coloured by copper and iron.

Type-Metal—See page 73.

Ultramarine—A valuable blue pigment of complicated composition containing alumina in the form of silicate.

Umber—A natural oxide of iron allied to ochre.

Uranium—See pages 96 and 106.

Urea (CH_4N_2O)—A constituent of urine resulting from oxidation of nitrogenous bodies in the animal organism. An adult man excretes about 30 grammes daily. It is one of the so-called organic bodies that has also been built up synthetically from so-called inorganic materials.

Uric Acid ($C_5H_4N_4O_3$)—A constituent of urine forming the principal part of urinary calculi and deposits.

Vacuum—A space devoided of air or gas as far as practicable, as, for example, the exhausted glass bulbs used for electric lighting.

Valency—See page 23.

Vanadium—See page 107.

Varnish—A solution of certain hard gums dissolved in turpentine (also alcohol) and linseed or boiled oil. Used as a protective coating to painted and wooden and other surfaces. (See also Gums.)

Vaseline—A solid jelly-like hydrocarbon obtained as a residual product left behind in the retorts from the distillation of crude natural petroleum, and subsequently purified from associated bodies.

Vegetable Matter—See pages 15, 40, 54, 66, and 67.

Verdigris—A green-coloured carbonate ($CuCO_3,Cu(HO)_2$) which forms on copper when exposed to damp air. (See page 9.)

Vermilion—See page 91.

Viscous—Thick, sticky, glutinous, or ropy.

Vitreous—Glassy.

Vitriol, or Oil of Vitriol—Another name for strong sulphuric acid.

Volatile—Light, ethereal, easily passing from liquid to gaseous state. (See page 3.)

Vulcanite—Is made by heating 2 parts of indiarubber with 1 part of sulphur to a temperature of about 150° C., and is largely used for making combs and other articles. Gutta-percha is vulcanized in the same way. (See page 103.)

Water—See pages 62 to 65.

Water-Gas—Is obtained by passing steam over red-hot coke, which has the effect of decomposing the water-vapour and producing a mixture of hydrogen and carbon monoxide gases:

$$C+H_2O=H_2+CO.$$

To make this mixture of gases (which otherwise burns when lighted without flame) luminous when burning, it is mixed with oil vapours, and it is also employed for mixing with ordinary coal-gas.

Water-Glass—See page 98.

Waxes—There are many waxes of animal and vegetable origin, of which beeswax is one of the best known.

Cerasine is another natural wax, which is largely used for mixing with and as a substitute of beeswax. Chinese wax or vegetable spermaceti is produced on certain trees by the puncture of an insect. These waxes are for the most part complicated compounds of carbon and hydrogen, and some contain oxygen in small proportions.

Weight—The force by which the mass of a substance is attracted by gravity.

Weights and Measures—See page 33.

Welsbach Light—See page 38.

Whisky—Spirit distilled from wort prepared from malt.

White-Damp—See page 68.

White-Lead—See Lead.
Willesden Paper—See page 81.
Witherite—See page 74.
Wolfram (Tungsten)—See page 106.
Wood's Fusible Metal—See page 74.

Zinc—See page 107.
Zinc Blende—See page 102.
Zinc White—See page 107.
Zirconium—See page 108.
Zircons—Natural silicates of zirconium.

PART V

CHEMICAL APPARATUS AND EXPERIMENTS (ILLUSTRATED)

The Laboratory—A chemical laboratory (workshop) consists essentially of a working bench or table about three feet from the ground, fitted with drawers and a shelf running along the back, upon which can be placed the chemical solutions (reagents) which are more or less in daily use. The bench should be provided with either a lead-lined wooden or a porcelain sink and a water-supply pipe with one or more taps; also a gas-supply pipe with two or three tee-piece connections and taps, to which the various lamps and burners ordinarily used can be attached. In cupboards or on a shelf below, may be placed the larger pieces of apparatus and supplies of chemicals that are only occasionally wanted, whilst the drawers in the bench are useful for the storage of small appliances and requisites.

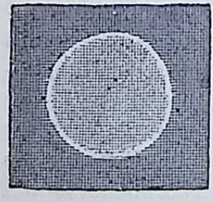
Absorption Bulbs—See Potash Bulbs.

Air-Pump—A mechanical appliance provided with valves used for pumping air into or withdrawing (exhausting) it from a vessel. The hand and foot pumps used for pumping up cycle tyres are illustrative, whilst an ordinary syringe is useful for many purposes, although it has not any valves. Amongst other applications, air-pumps are used in laboratories in association with desiccators for evaporating operations conducted at the ordinary temperature of the atmosphere, in order to reduce the atmospheric pressure and thus promote the evaporation from the containing vessel, and at the same time to remove the aqueous vapour coming from the substance being desiccated (dried) in the partially vacuous space, which may not already have been absorbed by any appliance placed therein for that purpose. (For illustration, see Desiccator.)

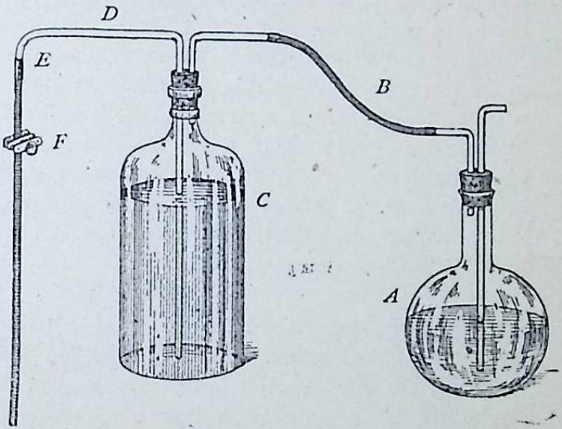
Apparatus (Chemical) means the utensils and appliances ordinarily employed in laboratories, and they can be obtained from Messrs. John J. Griffin and Sons, Ltd., of Kingsway, London, W.C., and Messrs. Baird and Tatlock, Ltd., of 14-15, Cross Street, Hatton Garden, London, E.C.

Argand Burner—An old type now rarely used and quite dispensable.

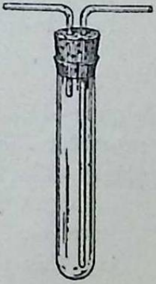
Asbestos (see page 113) withstands heating to a high temperature, and, as it is not acted upon by many chemicals, is often employed in laboratories; for example, in the form of fibres for plugging the ends of glass tubes in order to retain their chemical contents within prescribed limits. In the form of woven mats or cloths it is useful as a soft, non-conducting material on which may be stood flasks or beakers containing hot solutions. It is also used as a covering for the central part of wire gauze (as shown in the figure) used on the top of iron tripod-stands, thus preventing oxidation by rusting, affording a softer seat for glass vessels placed thereon when required to be heated by lamps below, and for the better distribution of the flame. In the fibrous form it also finds employment as a filtering material wherewith to plug the necks of funnels for separating solid and liquid materials, particularly when it is known that a paper filter would become easily clogged or destroyed by the chemical mixture; and although the filtrate may not be quite clear, it then admits of more rapid and perfect filtration through an ordinary paper filter.



Aspirator—An arrangement for aspirating or drawing a current of air or other gas through a vessel or through a liquid contained in one. When only a small volume of air is wanted, a fitted-up Winchester bottle (as shown in the figure) may be used. *A* represents a flask containing the liquid through which it is desired to draw the current of, say, air; *B* rubber tubing connecting glass tube from *A* to glass tube going just through the cork of the Winchester, *C*; *D* glass tube going to bottom of *C* and joining up at *E* with a length of rubber tubing dropping down into the sink of the laboratory, but fitted at *F* with a



pinch-cock for regulating the flow of water from *C* into the sink. The flow is first of all started by sucking at the end of this rubber tubing and thus drawing the water from *C*, the flow being subsequently regulated by closing or relaxing the pinch-cock (*F*). In this manner *D* really acts as a siphon-tube. (See Siphon.)



An ordinary test-tube of from ¾ to 1 inch diameter (see Test-Tube) can be fitted up to serve the same purpose on a small scale by means of a cork provided with two borings through which pass two small glass tubes arranged in the same fashion as in flask *A*.

A simple arrangement of this kind (as shown in the figure) can be used in connection with an aspirator by beginners for carrying out some interesting chemical interactions, as, for example, the following:

Wet Oxidations (for dry oxidations see Combustion-Tube).—*A*. Dissolve a few crystals of ferrous sulphate ($FeSO_4 7H_2O$) in 10 c.c. water in a test-tube, then add to it a dilute solution of potassium hydroxide (KHO) until no more precipitate of ferrous hydroxide is formed. Now insert the cork fitted as described and connect it with an aspirator, and draw a current of air through the mixture in the test-tube, and it will be seen that the greenish-grey precipitate of ferrous hydroxide is gradually converted by oxidation—absorption of oxygen from the air—into (hydrated) ferric oxide, the colour changing to reddish-brown. Leaving the water of combination out of consideration, the interaction is as follows:

$$2FeO + O = Fe_2O_3.$$

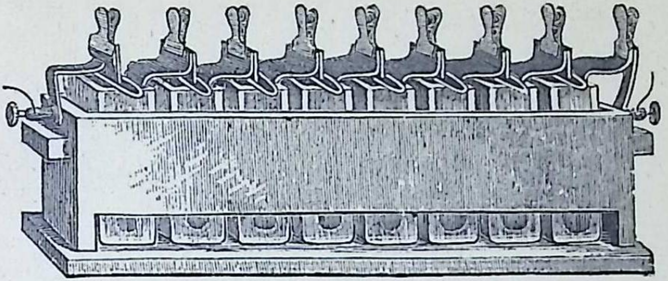
B. Similarly, take a dilute (5 per cent.) solution of manganese chloride and add to it a dilute solution of sodium hydroxide (NaHO) until no more precipitate is produced. Then connect as before with the aspirator, and it will be seen that by the passage of air, the precipitated manganese hydroxide, which is nearly white, also absorbs oxygen from the air and becomes converted more or less into a higher oxide (manganese sesquioxide), the change becoming visible by the blackening that ensues. Again leaving the water of combination out of consideration, the interaction is as follows:

$$2MnO + O = Mn_2O_3.$$

Balance—Delicate weighing apparatus. (See Scales.)

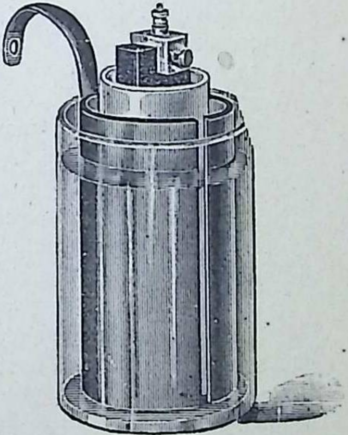
Barometer—See page 55.

Battery (Electrical)—An illustration is here given of Grove's battery, which has been described on page 47. The inner porous cells are charged with strong nitric acid and contain thin sheets of platinum, while the outer glass cells

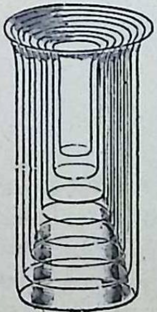


holding the zinc plates are charged with dilute (1 : 7 sulphuric acid.

The next illustration is of a cylindrical cell of Bunsen's carbon battery, consisting of an oblong prism of carbon, a zinc cylinder, a porous pot, glass cell, and binding clamp. In this battery the carbon replaces the platinum sheet of the Grove's battery (see page 47), and is connected with the zinc of the next cell by means of a copper strip.



Beakers are thin glass vessels made of such a quality as to withstand exposure to heat, cylindrical in shape with flat bottoms, and are sometimes provided with a lip to facilitate the transfer of contents. They are supplied, in nests, of various sizes from quite small ones up to a capacity of a litre (1,000 c.c.) and more (see figure).



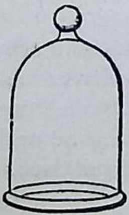
They are not only used for holding and heating liquids, but also for effecting many chemical operations. For instance, supposing it is desired to obtain a quantity of silver chloride in precipitated form, a solution of silver nitrate ($AgNO_3$) may be prepared in one beaker and a solution of sodium chloride ($NaCl$) in another, of such calculated strengths and quantities as to produce a known amount of the products. Upon admixture the following interaction ensues :

$$AgNO_3 + NaCl = AgCl + NaNO_3.$$

The silver chloride is precipitated in a white, heavy, curdy form, which can be consolidated to some extent by heating the mixture and stirring. After cooling and settling, the supernatant fluid can be decanted or siphoned off, leaving the bulk of the precipitated silver chloride at the bottom of the beaker in which the admixture took place, and this can afterwards be transferred or swilled on to a filter and its washing completed thereon. (See Wash-Bottle.)

Again, a small beaker may be employed to illustrate the preparation of soft soap, by taking 2 or 3 grammes or c.c. of castor oil and adding to it about 2 or 3 c.c. of potassium hydroxide solution (of specific gravity 1·15), stirring meanwhile, and gently warming the mixture on a sand-bath for some ten minutes. The oil is thus saponified into a clear translucent mass of soft soap, containing the separated glycerine in admixture, and the product will be found to be soluble in cold and warm distilled water. (See Soap, page 143.)

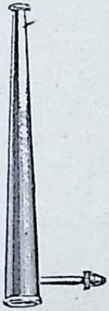
Bell-Jar—A glass jar of bell shape used for covering other vessels and for other purposes. (See Desiccator.) A bell-jar can be usefully employed for demonstrating the fact that combustion is necessarily dependent upon the oxygen that is contained in the air (see page 54). Place a lighted night-light on a glass plate, and then cover it with the bell-jar. It will be observed that the combustion will go on for a short time only, after which the light



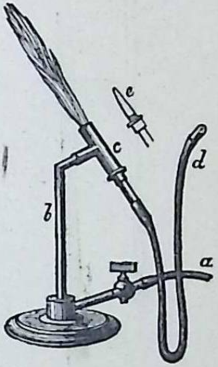
will go out by reason of the oxygen of the air being used up to such an extent that there is not enough left to support the combustion, the residual gases being the nitrogen constituent of the air and the carbon dioxide produced by the burning night-light.

Blow-Pipes—Appliances for intensifying the heat of flame by blowing air into admixture with the burning gas. Some are made to use with bellows, and smaller ones (as shown in the one illustration) are made for use with the mouth. (See also Acetylene and Oxy-Hydrogen Flame.)

The tube *d* shown in the second figure is connected with a bellows worked by the foot, the gas being admitted and regulated by the tap in tube *a*. As to the character of the blow-pipe flames, see Bunsen Burner.



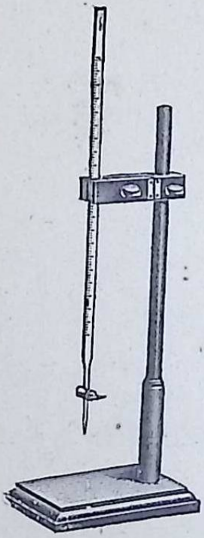
Mouth Blow-Pipe.



Bottles are generally made of glass, some with narrow mouths for containing liquids and others with wide mouths for containing solid substances. Some are fitted with corks and others with glass stoppers. There are also gutta-percha bottles for holding liquids that act upon glass such as hydrofluoric acid. (See also Winchesters.)

Bulbs—See Potash Bulbs; also Glass Tubes.

Burette—A graduated glass tube, open at the top and drawn out below, fitted with a glass stopcock, or rubber tubing and a pinch-cock, for delivering measured quantities of liquids. When in use it is held in a burette-stand as in figure. An interesting and instructive experiment may be made, using a burette, by filling it with a dilute solution of sodium hyposulphite ($Na_2S_2O_3$) and allowing it to drop into a previously prepared flask containing a solution of potassium iodide acidulated with 1 : 4 sulphuric acid and sufficient potassium dichromate to set free enough iodine to give the solution a good colouration. It will be observed that as the hyposulphite drops into the mixture the colour grows less and less and at last entirely disappears. Knowing the strength of the hyposulphite solution, it is easy to calculate from the known chemical interaction that takes place how much iodine was present as such in the solution, and this experiment affords a basic understanding of quantitative chemical analysis by the so-called "volumetric" process.



The interaction in this particular instance is as follows:

$$I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6—$$

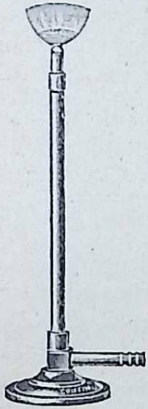
that is to say, potassium iodide and sodium tetrathionate are produced.

N.B.—If a little starch solution be added to the iodine solution, it will be found to give a beautiful blue colouration (due to the combination), and this is used in practice, as the blue colouration is so much more evident than that of the iodine towards the completion of the change.

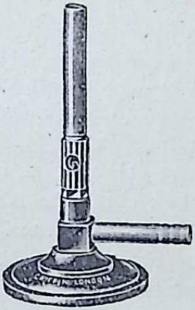
Burners—Gas-burners used in laboratories are of various types, according to the application that is to be made of them, apart from those used for illumination.

Fish-Tail Burner—This resembles the old-fashioned sort used for lighting rooms, the flame of which is like a fish-tail or bat's wing in general form, as shown in figure. It is chiefly used in connection with the bending of glass tubes (see Glass Tubes), and may be attached directly to the gas-supply pipe running along the working bench or fixed on an upright stand and connected therewith by means of a rubber tube. The luminosity of the flame is due to the imperfect combustion of the gas, and consequent production of minute particles of the carbon constituent in an incandescent form.

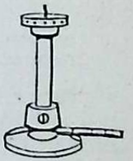
Bunsen Burner—This consists of an iron or brass tube fixed to a stand, and is fitted with a mechanical arrangement below, whereby air can be admitted in regulated amount into admixture with the gas before burning. The gas issues from a small jet at the base of the tube, and the air is admitted through several small holes also situate near its base, the amount of air being regulated by a movable disc of metal capable of closing these openings more or less as desired. In practice there is used about 1 part gas to 2½ parts of air. By this admixture the heat is intensified, perfect combustion of the carbon of the gas, as also the hydrogen, being secured, thus producing a practically smokeless blue flame. Such burners are often provided with a movable ring which fits on to the top of the burner-tube, so that the flame may, when desired, be broken up and made to assume a rose or ring like form of a number of small blue flames, in place of the long vertical column of flame. Both of these forms are employed for heating liquids contained in flasks or beakers,



Fish-Tail Burner.



Bunsen Burner.



Bunsen Burner
with Rose Top.

or for heating solid substances contained in crucibles, dishes, etc.; also for applying heat to sand-baths, water-baths, and water-ovens.

The flame of a Bunsen burner (like all ordinary flames) consists of two cones—the inner one, in which heated but imperfectly burned gases exist; and the outer one, where oxygen is in excess on the outside edge. Upon holding a bright copper wire across the flame so as to bisect (cut across) the inner one, the wire will become coated with black copper oxide at the outer edges, while that part in the centre will remain bright. If now the blackened part be placed in the inner cone, the oxide will be reduced again to the metallic state, parting with its oxygen constituent to the gases in course of combustion. The outer area is consequently called the *oxidizing flame*, and the inner cone the *reducing flame*.

Coal-gas (see page 71) consists to a large extent of hydrocarbons—that is, compounds of carbon and hydrogen—and if a jet of it be burned in a current of air, water and carbon dioxide will be found among the products of its combustion. To put this to the test, light a Bunsen lamp, turning the flame as low as possible and hold over it a beaker, and note the condensation of water that takes place therein. If the beaker be quickly covered with a glass plate for the moment, and then removed whilst some lime-water be placed therein, it will be noticed that the lime-water, upon shaking, will become white and turbid, owing to the formation of calcium carbonate—

$$CaH_2O_2 + CO_2 = CaCO_3 + H_2O ;$$

or, leaving the water in combination with the lime out of consideration,

$$CaO + CO_2 = CaCO_3.$$

Blow-Pipe Burners. (See Blow-Pipes.)

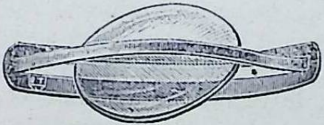
Charcoal—A small block of charcoal is often used for experimental purposes, one of which may be illustrated by taking a little powdered tin monoxide (stannous oxide), mixing it with an equal quantity of sodium carbonate, and heating the mixture when placed in a small hole (previously made in the charcoal) by means of a mouth blow-pipe—that is, by directing the reducing flame upon it. The mixture melts and the tin is reduced to the metallic state in the form of globules, which can be seen after the experiment by scraping away the residue and charcoal in which they are encased:

$$2SnO + C = CO_2 + 2Sn.$$

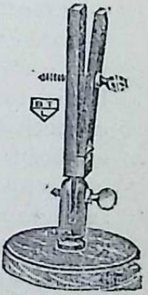
Similarly, if a little red-lead be placed on a piece of charcoal and strongly heated in the reducing flame with a mouth blow-pipe, it will be seen to be reduced to the metallic state. (See Bunsen Burner.)

Chloride of Calcium Tube—See Drying-Tube.

Clamps are fasteners or clasps, and are of various descriptions according to their intended use, including flask-clamps, burette-clamps, and clamps to hold Liebig's condensers. (See Retort.) They are of the same general description, but are adapted to the special requirements, and are, as a rule, attached to stands and secured thereto like the rings of a retort-stand. (See Retort-Stand.) There are also clamps for holding two watch-glasses (provided with flat ground edges) together, this combination being often employed for holding small quantities of solid chemical substances which are the subject of investigation. (See also Test-Tube Holder.)



Watch-Glasses in Clamp.

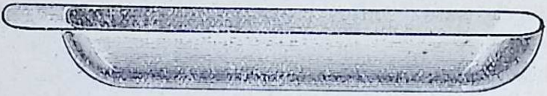


Wooden Clamp with Joint at Foot for Flasks, etc.

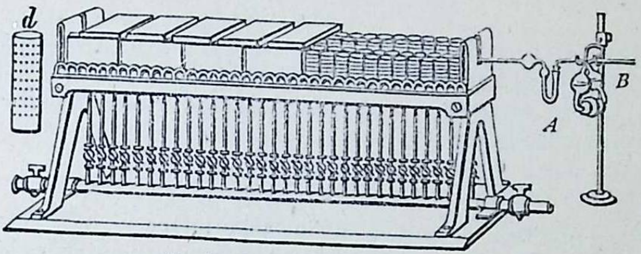
Clip—See Pinch-Cocks.

Clock-Glasses are shallow concave glasses of various sizes, and are used for covering beakers, dishes, etc.

Combustion-Tube—Combustion-tubing is made of glass, porcelain, or silica, of about $\frac{3}{8}$ or $\frac{1}{2}$ inch diameter. Its name is derived from the fact that it is employed very extensively in the analysis, by combustion, of organic substances—say, for example, sugar. A small vessel or boat (as shown in figure) made of platinum, porcelain, or silica (small enough to be pushed into the combustion-tube), is taken and weighed, and there is then placed in it a small quantity of the sugar (previously dried at 100° C. in a water-oven), admixed with oxide of copper so as to moderate the action of the air or oxygen gas, as presently described. The weight of the dried sugar is ascertained by again weighing the boat after its introduction. The tube containing the boat is then placed in a so-called combustion furnace (as shown in figure) suitably equipped and connected with, first of all, a drying-tube of previously ascertained weight, and then with so-called potash bulbs charged with a solution of potassium hydroxide, also of previously ascertained weight. A current of dried air or oxygen gas is then passed through the combustion-tube, which is gradually heated to redness in the furnace. This causes the decomposition of the sugar, which consists of carbon, hydrogen, and oxygen ($C_6H_{12}O_6$), with the result that the carbon is burned off as carbon dioxide (CO_2) and the hydrogen as water (H_2O). The water is absorbed by the sulphuric acid contained in the drying-tube (*A*), and the carbon dioxide is absorbed by the potash in the potash bulb (*B*); and these being severally weighed after the combustion is completed, it is known

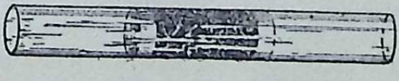


that the increases in weight of the two appliances are due to these absorbed gases, and knowing, again, how much carbon and hydrogen are severally contained in given quantities of carbon dioxide and water, it is easy to calculate the quantities therefrom. These will be found to make up so much of the weight of the sugar, and the other part necessarily consists of oxygen, which is the only other constituent of the sugar, and which it is therefore unnecessary to specifically determine otherwise. (See also Furnaces, Drying-Tube, and Potash Bulbs.)



Combustion Furnace as in Use.

Short lengths of clear-glass ½-inch combustion-tubing may be used by beginners for a number of simple experiments. For example, (1) take a length of, say, 6 inches and lightly plug one end with asbestos fibres, then introduce some copper turnings occupying about 1 inch in the centre of the tube, plug the other end as the first one, and push up the plugs with a glass rod so as to retain the copper turnings in position (see illustration). Now insert a cork at each end fitted with a short glass tube through the centre, and having placed the tube across a tripod-stand or secured it by two clamps (one at each end) attached to stands, connect the glass tube at one end with an aspirator, and draw air through the tube whilst



that part which holds the copper turnings is strongly heated by a Bunsen flame. The oxygen of the air will be observed to gradually turn the copper black in colour by its conversion into oxide,

$$Cu+O=CuO.$$

If desired, the oxide can be again reduced to the metallic state by passage of a stream of hydrogen gas under similar conditions :

$$CuO+H_2=Cu+H_2O.$$

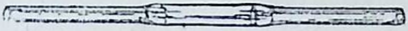
(2) Place a globule of metallic mercury in a small porcelain boat, and push it into a combustion-tube as in (1) ; then heat the tube near where the mercury is situate, meanwhile drawing a slow current of air through the tube, when the mercury will gradually be vaporized and converted to some extent into the red oxide, both the vaporized metal and the red oxide being deposited in the cooler part of the tube, as described on page 8.

(3) Place a little red oxide of mercury in the boat, and heat strongly after placing it in the combustion-tube, and note the decomposition into mercury (which will be deposited in the metallic state in the cooler part of the tube) and oxygen gas (see page 9).

Condensers—See Liebig's Condenser.

Connectors include india-rubber tubing, which is often used for connecting glass tubes of approximately the same diameter. Larger rubber tubing (ordinary and vulcanized) is much used in laboratories for connecting lamps and gas-burners with the fittings or taps of the supply-pipe, also in connection with condensers.

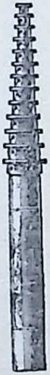
In some cases, as, for example, when the chemicals employed are known to have a destructive action on rubber, a glass connector is employed, being another short length of tube somewhat larger in diameter than the other two glass tubes to be connected, so that the ends of the last named may just enter the larger tube, as shown in the figure, the joints being made tight by means of melted paraffin wax.



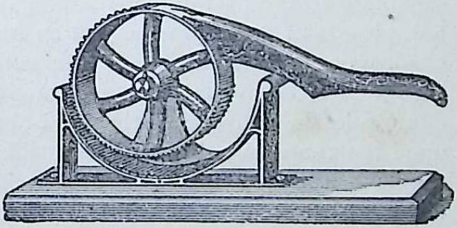
Corks are made from the outer bark of the cork-tree, and admit of squeezing to some extent. They are used for sealing or stoppering bottles, flasks, and tubes.

Cork-Borers are hollow metallic tubes of brass or steel, with sharpened ends for boring holes through corks.

Cork-Squeezer—A mechanical contrivance for squeezing corks, as found necessary to adjust their fitting well as stoppers.



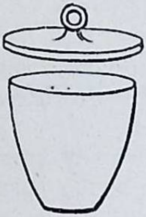
Set of Cork-Borers.



Cork-Squeezer.

Crucibles—These are vessels or pots employed for heating solid chemical substances to a high temperature or for melting metals, etc. Crucibles are variously made of earthenware, plumbago, porcelain, silica, platinum, iron, silver and nickel, but the metallic ones may not be employed for melting metals or under circumstances in which another metal may be reduced from the compound in use to its free (uncombined) state, on account of the danger of damaging or ruining the vessel through the production of an alloy (see Alloys)—that is, a combination of the other metal with the metal of the crucible.

Amongst other practical applications of crucibles may be mentioned their employment for incinerating compounds of partly organic nature with the view of burning off the organic constituents.



Porcelain Crucible.

A porcelain crucible may be used experimentally by placing some powdered sulphur in one, and above this a small quantity of metallic copper turnings. If now the crucible be placed on a wire triangle, and that in turn on a tripod-stand (which see), and heated from below by a Bunsen lamp, it will be seen that the sulphur will gradually melt, darken in colour, and presently boil, and that when the hot sulphur touches the copper—at which stage the lamp should be removed—the metal turnings will become red-hot, glow, and drop into the molten sulphur, forming a black mass of copper sulphide. After cooling, the crucible should be carefully placed on a clock-glass, and if now a dilute solution of hydrochloric acid be gradually dropped upon the contents, a decomposition will take place which results in the formation of hydrogen disulphide gas (the unpleasant smell of which will be readily perceptible) and cupric chloride, which passes into solution :

$$CuS + 2HCl = CuCl_2 + H_2S.$$

This, again, can be proved by taking out the crucible, placing it in a beaker, and then covering it with water, when the cupric chloride will become dissolved. Pour off some of the clear solution into a test-tube, and then add a dilute solution of ammonium hydrate drop by drop, when it will be observed that first of all a pale blue bulky and flocculent precipitate of cupric hydroxide ($Cu(HO)_2$) is produced, and upon adding more ammonia it will become dissolved, forming a deep blue solution. Such a solution is used in commerce for dissolving cellulose (see page 117).

Another experiment may be made, using a porcelain crucible, to illustrate the generation of hydrofluoric acid and its etching properties. Place about 4 or 5 grammes of powdered fluorspar (CaF_2) in the crucible, add enough strong sulphuric acid drop by drop to make a paste of the two substances, and then stand on a heated sand-bath. Next, take a watch-glass and coat the under side with a thin layer of melted paraffin wax, and after cooling, mark letters or some figures through the wax with the point of a needle or pen-knife; then place it over the top of the crucible and allow it to remain there for some hours. Upon removing the wax from the surface of the watch-glass by warming and wiping it clean, the etching effect will be observed (see page 82):

$$CaF_2 + H_2SO_4 = CaSO_4 + 2HF.$$

Make a mixture of litharge (lead oxide) with powdered charcoal, place it in a porcelain crucible, and heat the mixture, using a foot blow-pipe, and observe the separation of metallic lead—

$$2PbO + C = CO_2 + 2Pb.$$

Take a saltspoonful of sawdust, place it in a porcelain crucible, and dry on a warm sand-bath; then carefully add a small quantity of strong nitric acid, which by furnishing it with oxygen causes its ignition and combustion.

Platinum crucibles are largely used for fusing inorganic substances, and by way of illustration a teaspoonful of dry common salt may be placed in one and fused over a Bunsen flame. Taking the crucible by a pair of tongs, the fused salt may now be poured out on an iron or tin-plate saucer, and then, after cooling, it may be broken up into small pieces and used experimentally in making hydrochloric acid gas as described under Flasks. (See page 180.)

Porcelain crucibles may also be used to examine the action of heat upon sugar and wood. Cane-sugar may be observed to melt (at about 160° C.) to a clear liquid, forming upon cooling what is called *barley-sugar;* and at a higher temperature (about 210° C.) decomposition takes place, water being given off and so-called *caramel* being produced. Upon further heating, destructive decomposition sets in, a mixture of inflammable gases (containing carbon monoxide, carbon dioxide, and methane) is evolved, together with water, acetic acid, and a number of other compounds, a carbonaceous mass remaining in the crucible.

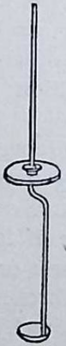
Wood or sawdust may be observed to darken and char upon exposure to heat, the decomposition commencing slowly at about 140° C. The products, to some extent, are identical with those derived from sugar as above described.

Cylinders—Glass vessels of vertical shape, sometimes stoppered, and of varying sizes, with flat bottoms or stands for holding chemical preparations (solid and liquid).

Deflagrating-Spoon—A simple form is shown in the figure, and consists of a metallic wire or rod terminating at the lower end in a small iron or other metallic spoon or cup to hold the desired chemical substance, and fitted above with a metallic plate or with a cork, which may be ascertained beforehand, to fit a wide-mouthed stoppered jar or bottle, in which it is planned to make the experiment.

A small piece of phosphorus of the size of a pea may be placed by means of a pair of pincers in the small cup, then gently warmed over a lamp so as to set it on fire, and if inserted quickly in a bell-jar or bottle previously filled with oxygen gas, the effects described on pages 16 and 38 will be witnessed.

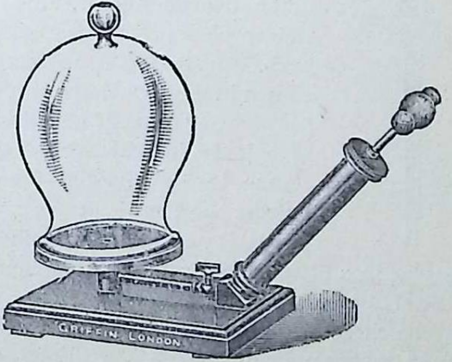
N.B.—The phosphorus should always be cut under water on account of its inflammable and poisonous character, and this experiment should not be made by beginners unless under the immediate control of a qualified teacher.



Deflagrating-Spoon.

A wide-mouthed stoppered bottle previously filled with oxygen gas (as described under Pneumatic Trough), may also be employed to make the experiment of burning a strip of metallic magnesium foil, as referred to on page 89. Cut a strip of the foil about 6 inches in length and ¼ inch in width, hold it at one end with a pair of tongs, light the other end in a Bunsen flame, quickly remove the glass stopper from the vessel of oxygen gas, and lower the strip of burning metal into it. It will be seen that the combustion of the metal proceeds with much greater intensity and luminosity in the oxygen gas as contrasted with air, and that the metal is converted into magnesium oxide—a white powder which becomes deposited in the bottle.

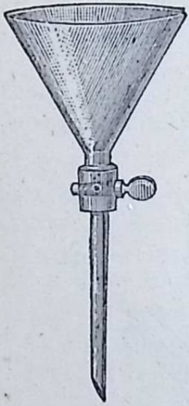
Desiccator—A drying appliance designed to remove water from chemical substances. A common form consists of a segmented porcelain basin containing strong sulphuric acid, standing on a glass plate having a ground surface and covered with a closed bell-jar, having also ground edges slightly coated with grease. The liquid or solid preparation to be dried (desiccated) is placed in a smaller vessel of glass or platinum or other material on the



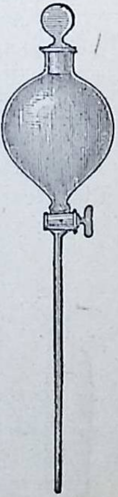
N.B.—This Figure of an Air-Pump and Desiccator does not show the Sulphuric Acid Basin.

vessel containing the strong sulphuric acid, which, having a strong affinity for water, absorbs the moisture evaporated from the substance undergoing the drying process. Sometimes this appliance is coupled up with an air-pump to facilitate the process. By greasing the plate as well as the edges of the bell-jar, the combination is made airtight. (See Air-Pump.)

Digesters—Vessels in which substances may be digested—that is, exposed to the action of a chemical liquid at any suitable temperature for the purpose of extracting constituents known to be soluble therein. Thus, an ordinary flask or beaker or retort may be employed in many instances, the liquids being decanted, siphoned or otherwise drawn off from time to time, and replaced by a fresh supply of solvent (water, alcohol, ether, benzene, etc.). In other cases particular pieces of apparatus are used. One such consists of a vessel as shown in figure, being a sort of "separating funnel," consisting of a body in which the substance to be digested (be it powder, or lumps, or parts of plants) is placed and contained, maybe, in a filter-paper or placed upon some other strainer. The container terminates in a tube fitted with a stopper through which the extract may be drawn off.

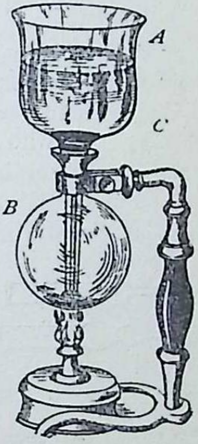


In other cases, as for example, when an oily liquid is known to be a mixture of two or more substances, one of which is soluble in a certain solvent and the other insoluble, an appliance such as is shown in the second figure may be employed. This is a "stoppered separating funnel," and consists of the globular body in which the mixture can be shaken up or agitated

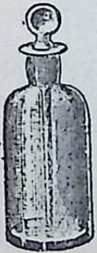


with the solvent liquid, and then, following upon the separation which takes place after standing for a time, the extract can be drawn off from below through the stoppered neck of the apparatus.

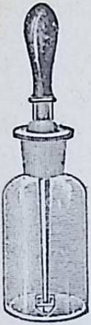
Another useful form of digester or percolator is the apparatus now widely used for preparing coffee for drinking purposes—namely, the so-called "Cona" appliance, as shown in the figure. The coffee which it is desired to submit to percolation is placed upon the strainer *C* in the digester *A*, the tube of which passes through a cork fitting into the reservoir *B*. On boiling the water which is placed in *B*, by means of a spirit-lamp, it is forced up by the pressure of the steam which is generated, and after removing the lamp, the water which has thus been forced into *A* percolates through the coffee (or other substance which may be placed therein), and then gradually flows down again into *B*. The operation can be repeated as often as necessary. (See also Water-Bath.)



Distilled Water is commonly used in laboratories for making chemical reagents and for solvent and washing purposes generally, because ordinary water contains small quantities of mineral substances, and requires, in fact, to be distilled in order to get rid of such impurities. (See Water-Oven.)



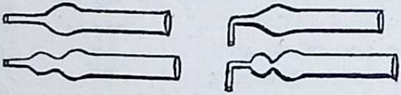
Drop-Bottle—A simple appliance for providing drops of liquids for testing purposes, consisting of a bottle fitted with a long, tapered, solid glass stopper, as shown in the figure, so that when the stopper is withdrawn a small quantity of the liquid adheres to it and may be dropped

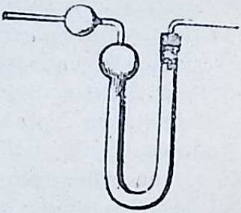


into any solution or on to any solid substance to be tested.

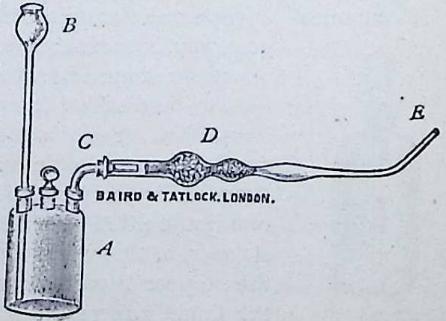
The other arrangement is somewhat similar, but in this case it is a hollow tube or small pipette that passes through the cork, and is drawn out to a fine point at the lower end. By use of the compressible rubber bag at the upper end of the tube, as much of the liquid as is desired may be retained in the tube and removed for testing purposes.

Drying-Tubes—Appliances used for drying gases (freeing them from water) in the several forms shown in the figures. Some are straight-shaped tubes packed with small lumps of calcium chloride ($CaCl_2$), which substance has a great affinity for moisture. For example, if it be desired to dry a current of carbon dioxide gas as generated from calcium carbonate and hydrochloric acid, the arrangement of apparatus as shown in the next drawing serves the purpose. This shows a so-called Woulfe's bottle (*A*), in which may be placed small broken lumps of marble (calcium



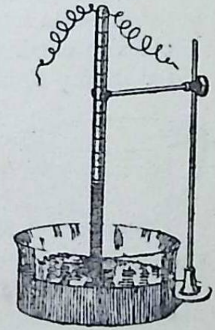


U-Shaped Drying-Tube.



carbonate), covered with water. It is fitted with a thistle-funnel (*B*), passing through a cork with which the neck is sealed, and down which dilute (1 : 4) hydrochloric acid is poured. The current of carbon dioxide thus generated (and containing moisture dissolved in it) passes away through the connecting tube *C* (which is held by the cork at that neck) into the drying-tube *D*, with which it is similarly connected, and passes out at *E* denuded of its moisture. Instead of using the drying-tube with calcium chloride, a **U**-shaped tube sealed at the bend with strong sulphuric acid may be employed, as it also has the property of absorbing moisture contained in gases bubbled through it, such, for example, as those which are generated by burning organic substances in a current of dry air or oxygen, and the increase in the weight of the tube gives the weight of the water thus absorbed, and from it may be calculated the proportion of hydrogen contained in a known weight of the organic substance employed. (See Combustion-Tube.)

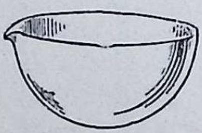
Eudiometer—A simple form of this apparatus, used for the examination of gases, is a long glass tube closed at the one end and open at the other, graduated into cubic centimetres by divisions etched on it. At the closed end thin wires of platinum are fused into and through the glass, and thence pass outside so that they can be connected with the wires of an electric coil. In using this apparatus to demonstrate the composition of water, a mixture of 2 volumes of hydrogen and 1 volume of oxygen is introduced into the tube, which is then inverted and placed with its open end in a trough of mercury. Upon now causing an electric spark to pass from end to end of the two wires within the tube, the two gases will combine with explosive force. In this way it is found that 2 volumes of hydrogen



and 1 volume of oxygen combine to form water, and if there be any excess of either gas contained in the mixture it will remain after the condensation that takes place in the eudiometer following upon the explosion. (See Voltameter.)

In laboratories where a mercury bath is available, this form of eudiometer may be used to demonstrate the proportion of oxygen present in a given volume of air by inverting the graduated tube containing some air (the rest of the tube being occupied by mercury) over the bath and introducing, by means of a pipette with a recurved end, a few cubic centimetres of a mixture of 1 part pyrogallic acid in 6 parts of water, rendered alkaline by the addition of caustic potash solution. This solution rises up through the mercury in the tube, absorbs the oxygen of the air, becoming dark brown in colour in consequence, and leaves the nitrogen unabsorbed, the relative diminution in volume thus becoming apparent.

Evaporating Basins or Dishes are used, as the names imply, for the purpose of evaporating solutions with the view of strengthening (concentrating) them, by getting rid of the excess of water or other solvent which holds the chemical substance in solution. They are also employed in many cases to obtain substances in a crystallized condition, or for drying solid masses or pasty mixtures by heating. They are made of various sizes, from 2 inches in diameter up to 12 inches or more, the larger ones being of porcelain, glass, and silica. Some smaller ones are made of silver, aluminium, platinum, and nickel (the choice being made according to the nature of the chemicals to be dealt with), and all are preferably provided with a lip to facilitate the transfer of their liquid contents to other vessels as and when required.


Evaporating Basin.

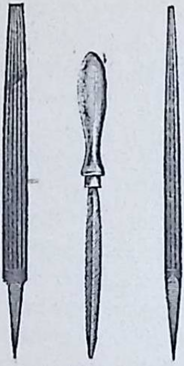
To illustrate their use, dissolve some common alum in cold water in a beaker until it will dissolve no more—that is, until it is saturated at that temperature—then transfer to an evaporating-dish placed upon a heated sand-bath, and go on heating and dissolving more alum in it until again it will not dissolve any more. Then allow to cool, and observe the formation of crystals which ensues consequent upon the deposition of that excess of alum which water will dissolve when heated, as contrasted with that smaller quantity it will hold in cold solution. Again, dissolve small quantities of potassium nitrate and sulphate of copper respectively, say 10 grammes each, in 100 c.c. of water, and evaporate the solution sufficiently, afterwards allowing it to cool, and note the formation of crystals, which will form slowly and be of a large size if the solution is not too concentrated.

A third experiment may be made by placing a lump of white sugar in a small porcelain evaporating-dish considerably larger than itself, pouring on it about 10 or more drops of strong sulphuric acid, and gently warming the mixture on a sand-bath, in order to observe the chemical changes that take place, as described on page 35.

A fourth experiment, to illustrate the making of hard soap, may be made as follows: place in a small dish about 5 grammes of lard or tallow and 10 c.c. of methylated alcohol, heat the mixture on a sand-bath, stirring meanwhile, and then gradually add a strong solution of sodium hydroxide ($NaHO$)—about 10 c.c.—and bring the mixture to the boil, meanwhile continuing the stirring. The fat will gradually become converted into soap by saponification (see Soap), as may be proved by testing its solubility in water after cooling and by use on the hands for washing them.

N.B.—Alcohol is not used in practical soap-making, and is only employed in this experiment to facilitate the saponification by dissolving the fat.

Files, as used in laboratories, are of three sorts—viz., triangular, round or rat-tail, and flat or rasp-like. The triangular ones are useful both for marking glass and assisting in the breaking of glass tubing. (See Glass Tubes.) The round ones are chiefly employed for filing smooth the holes made in corks by borers, or for enlarging them; whilst flat files are used for smoothing or reducing the diameter of corks and taking the ragged edges (by gentle rasping) off the ends of glass tubes, etc.



Files.

Filters or strainers provide the means of separating liquids from solids. The common form consists of a circular piece of porous paper made of a special quality which yields a minimum amount of ash when burned (incinerated). By folding it first of all into halves and then again into quarters, it will be found, when opened out, to fit into a funnel of appropriate size (see Funnels), the paper lying against the sides of the funnel. In common practice, the paper filter when so fitted and before use, is first of all moistened with a liquid of the same nature as that contained in the mixture to be filtered. Thus, for aqueous mixtures water is applied from a wash-bottle (which see), for alcoholic mixtures alcohol of the same strength should be used, and so forth.

Paper filters can in some cases be used for separating two liquids of different gravities that are not miscible—that is, cannot be mixed together so that they will not separate again after shaking and upon standing; for example, a mixture of turpentine and water or olive oil and water. In these instances, if the filter be first of all wetted with water and then used for filtering such mixtures, the watery (aqueous) part will pass through the filter paper, while the oily bodies will be retained more or less permanently on the filter, and may be there exposed to what further washing with water as applied by a wash-bottle may be desired.

There are filters or strainers of solid porous porcelain or earthenware which are sometimes employed for straining liquids from magmas or thick, moist mixtures of crystalline or other solid substances. These filters sometimes take the form of solid flat cakes or blocks on which the magma is placed (taking care that it does not overflow the edges of the strainer), and the liquid part gradually soaks or flows away through the texture of the filter block, leaving the more or less dry crystalline or other solid body on its surface. In other cases, filters are constructed of funnels having their necks plugged more or less tightly with various materials known not to be chemically affected by the materials to be filtered, as, for example, glass-wool, slag-wool, asbestos fibres, cotton-wool, flannel, etc.

In manufacturing and industrial operations, appliances constructed on this principle are extensively employed, particularly where huge volumes have to be dealt with, and when it is difficult to otherwise separate liquids from the mixtures to be dealt with. In laboratory practice some such preliminary filtration has often to be made before the clouded filtrate thus prepared can be more perfectly filtered—say through an ordinary paper filter as previously described.

Sand is used in waterworks for the filtration of water on a large scale, and there are many types of domestic filters in which the filtering principles are variously composed of porous porcelain, charcoal, spongy iron, etc.

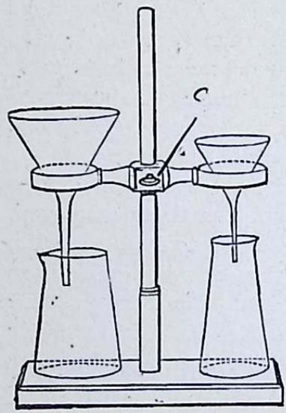
To illustrate the use of a laboratory paper filter, take a solution of barium chloride, add to it a dilute solution of sodium sulphate or sulphuric acid (1 : 4) until no further precipitate is obtained—

$$BaCl_2 + Na_2SO_4 = BaSO_4 + 2NaCl,$$
$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl,$$

and pour the mixture on to a filter prepared as described; the liquid part will pass through and the heavy precipitated white barium sulphate will be left upon the filter.

paper, on which it may be washed with cold or hot water, using a wash-bottle for that purpose (see Wash-Bottle), until it is free from all contamination with the soluble parts of the filtrate (the liquid that passes through the filter).

N.B.—In transferring the mixture on to the filter (particularly if the vessel containing it is not provided with a spout), a glass rod should be held against the test-tube or beaker containing the mixture, which can be poured down its length so as to avoid spluttering or splashing.

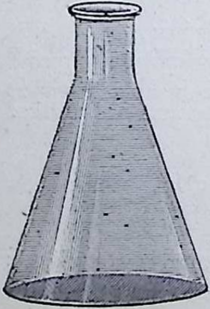


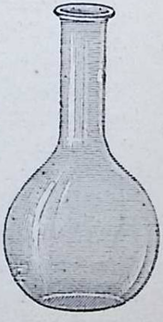
Filter-Paper—See Filters.

Filter-Stands are designed to hold funnels when used for filtering purposes, and an ordinary type is shown in the figure at side. It consists of a wooden stand fitted with rings at the ends of arms having a hollow socket fitting over the upright part of the stand, and secured at any desired height by screw-nuts (*C*) at the back. Ordinary retort stands may be used for the same purpose.

Fish-Tail Burner—See Burners.

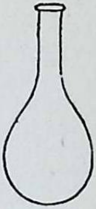
Flasks are glass vessels for holding liquids, of the shapes shown in the two next figures—that is, a body part with flattened bottom, and a neck which can be easily grasped by the hand or held by a clamp, and closed with a cork when required. The glass of which they are made is of a quality to permit the contents to be heated, when placed on a sheet





of wire gauze over a lamp or on a sand-bath, to the temperature of boiling water.

Florence flasks, a figure of which is also shown (originally used for containing olive oil), are, when available, and after being cleaned, very useful in chemical laboratories for various purposes. They have long, narrow necks and the bodies are of oval shape. They are of special service when it is desired to expose dry mixtures to a considerable temperature, as, for example, in the generation of oxygen gas from a mixture of 3 parts potassium chlorate and 1 part manganese dioxide (the latter being used to moderate the action)—



Florence Flask.

$$KClO_3 = KCl + 3O.$$

In this case the flask is fitted with a cork and a tube for the escape of the oxygen gas which is generated upon the direct application of heat to the flask. (See Pneumatic Trough.)

N.B.—Young students are advised not to make this experiment except under the direct superintendence of a teacher.

A small ordinary flask may be employed to illustrate the generation of chlorine gas by placing therein a small quantity of a mixture of manganese dioxide and common salt, then covering it with a previously prepared mixture of equal parts of sulphuric acid and water, and gently heating the contents on a sand-bath, when chlorine will be given off as a heavy yellow gas of strongly smelling and corrosive character—

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

Care must be taken not to breathe it, but two observations may be made with it as follows:

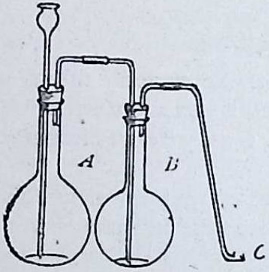
(A) Dip a watch-glass in a solution of potassium iodide, and, after draining it, hold it for some moments over the neck of the flask in which the chlorine is being generated, and observe the production of iodine thereon as set free by the decomposing action of the chlorine which replaces it in combination ; thus—

$$2KI + Cl_2 = 2KCl + I_2.$$

(B) Place a piece of wet coloured cotton rag over the neck of the chlorine flask, and observe the bleaching of the colour by the action of the chlorine. (See page 78.)

N.B.—So soon as these experiments have been made, fill the chlorine flask with water, pour the contents down the sink, and well flush afterwards.

Apart from using flasks in which to make mixtures of chemical substances and for heating their contents, they are often fitted up for special purposes—for example, wash-bottles (see Wash-Bottles), and in much the same way as a Woulfe's bottle is fitted (as described under Drying-Tube). That is to say, the neck is fitted with a cork or rubber stopper having two holes bored therein, and through which are passed and held thereby, a thistle-funnel and a shorter tube, as shown in the drawing. Say it is desired to prepare some hydrochloric acid gas. Place some small, broken-up lumps of fused common salt (prepared as described under Crucibles) carefully at the bottom of the flask, pour in strong sulphuric acid so as to well cover the salt and the lower end of the funnel tube; then place on a sand-bath, and secure it as may be necessary, as, for example, with a small ring of the retort stand that may be used to support the sand-bath. Now gently heat the sand-bath by means of a Bunsen or ring burner, when the following interaction takes place :



A is a flask fitted up as described.
B is a flask fitted up as a wash-bottle for the gas to be generated.
C is the end of the gas delivery tube as used with a pneumatic trough.

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl,$$

a steady stream of hydrogen chloride gas being evolved from the end of the shorter tube. The thistle-funnel is provided to add more acid as may be required.

Operating in the same way as above described, sulphur dioxide gas may be prepared by the action of strong sulphuric acid upon metallic copper :

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

N.B.—For these two experiments the wash-bottle shown in the illustration is not required.

Students are advised not to make these two experiments except under the direct superintendence of a qualified teacher. Test-tubes fitted up in the same manner may, however, be used by students for generating other gases, as described in the section on Kipp's Apparatus.

Foil, or a thin sheet of metal, finds frequent use at the hands of the chemist. Platinum foil is particularly useful, inasmuch as it is not acted upon by most chemicals and withstands exposure to high temperatures. It is consequently employed to test the behaviour of solid substances when exposed in crystal or powder form to heat varying from mere warming up to redness. For this purpose it is held by tongs or forceps.

Lead, copper, tin, zinc, aluminium, and magnesium, are also prepared in the form of foil, and are required from time to time in the laboratory.

Place a small quantity of crystallized borax ($Na_2B_4O_7$ $10H_2O$) on a piece of platinum foil, and heat over a Bunsen flame, when it will be seen to swell up, losing its water of crystallization, and finally fuse to a clear glass-like appearance.

Burn a small quantity of sulphur upon a piece of platinum foil and note the generation of sulphur dioxide by its characteristic odour.

Forceps—See Tongs.

Funnels are used for filtering purposes (see Filter-Stands), also for transferring liquids from one vessel to another, and are generally made of glass. Others made of pottery, iron, wood, copper, etc., find use for certain applications. They are of such shape that the narrow neck below can be inserted through the neck of a bottle or other vessel into which the liquid material is to be placed. At other times they are supported by filter-stands, tripods, or triangles (see Triangles), or on the rings of retort-stands (see Retort-Stands), according to circumstances. (See also Filter-Stands, Thistle Funnels, and Digesters.)

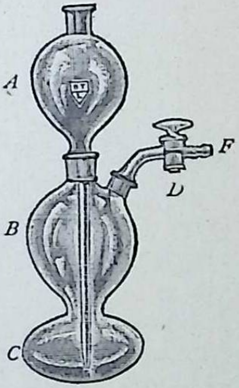
Furnaces, as used in laboratories, are of several descriptions. The electrical furnace is only to be found in highly equipped establishments, and some references to their use will be found elsewhere. (See pages 52 and 77.)

A so-called combustion furnace is extensively employed for exposing solid substances up to a red heat (but below that of the melting-point of the combustion tube that is employed) in a current of air, oxygen, or other gas, in order to study the effects produced, by subsequent examination of the gaseous and residual products, and still more often for the analytical determination of the constituents of organic substances. This furnace really consists of a great number of Bunsen burners set in a row and all rising up from a larger gas-supply pipe below, with which they are connected. They sometimes terminate in and are surrounded by hollow perforated cones or blocks of earthenware, as shown by *d* in illustration (on page 163), which has the effect of breaking up the flame and bringing the entire mass to a glowing red heat when in use. The framework is of iron, and so constructed that when the furnace is in use, the heat can be more or less concentrated on the combustion tube by means of earthenware tiles arranged at the sides, and which can also be placed over the top of the channel (running along and over the tops of the burners below) in which the combustion tube rests. (For illustration see Combustion Tube.)

Gas-Burners—See Burners.

Gas Generators—There are many forms of gas generators, but a common form is the Woulfe's bottle fitted as pictorially shown in the description of drying-tubes. Flasks properly fitted up are often employed, particularly when it is necessary to employ the agency of heat. (See Flasks.)

Kipp's apparatus for the generation of hydrogen disulphide (sulphuretted hydrogen), carbon dioxide, etc., in gaseous form, is of glass, and consists of three globular parts as shown in figure, the upper part terminating in a long tube which passes down through the middle one and reaches near the bottom of the lower one. To make hydrogen disulphide, iron sulphide in small lumps is placed in the glass reservoir *B*, and concentrated hydrochloric acid poured into *A* until *C* is filled and the acid rises to some extent into *B*, where it acts on the iron sulphide, liberating hydrogen disulphide. The gas can now be obtained by opening the cock *D*, and then it passes out at *F*. When not required, shut *D*, and the gas generated in *B* will then exert pressure on the acid left in *B*, and force it down into *C* and up into *A*, thus leaving the iron sulphide and the acid out of contact, gas, therefore, ceasing to be generated.



When it is desired to use this apparatus for the generation of carbon dioxide, lumps of marble ($CaCO_3$) are placed in *B* instead of the iron sulphide, and the working is the same. It may also be used for generating hydrogen gas, substituting granulated zinc again for the iron sulphide or the marble, but in this case it is desirable to place around the tube descending from *A*—that is, the annular space between it and the contracted part of the globe *B*—a disc of woven asbestos cloth on which the granulated zinc may rest, to obviate its passage by dropping into the globe *C*.

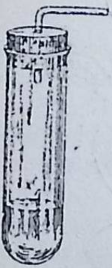
The preparation of H_2S, CO_2, and H gases can be made on a small scale, using test-tubes for effecting the requisite chemical interactions, as follows :

(1) $FeS + 2HCl = FeCl_2 + H_2S$.

(2) $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$.

(3) $Zn + 2HCl = ZnCl_2 + H_2$.

Dilute HCl (1 : 4) should be employed, and if each tube be fitted with cork and tube as shown in sketch, the generated gases may be tested respectively as follows :



(1) By passing the H_2S gas into another test-tube in which has been placed a piece of filter-paper steeped in a dilute solution of lead acetate, when it will be seen to blacken by the formation of lead sulphide.

(2) By passing the CO_2 gas into another test-tube previously rinsed out with lime-water, when it will be seen to whiten by the formation of calcium carbonate.

(3) By lighting the hydrogen gas as it issues from the jet of the small glass tube (drawn out to a fine point) emerging from the cork, and holding a small dry beaker over the burning jet to observe the formation of water.

(N.B.—Do not apply a light until enough time has elapsed for the generated hydrogen to displace the air in the test-tube in which it is generated.) (See also Flasks.)

Gasometer and Gasholder—Vessels for the storage of gases, and the method of filling small ones in laboratories is described under Pneumatic Trough.

Gas Tube (Graduated)—See Eudiometer.

Glass-Blowing—Glass-blowing can only be accomplished by practice, and here a simple illustration will suffice. Suppose it is desired to make a sealed tube with a bulb at one end, a piece of glass tube of the desired size and length—say $\frac{1}{8}$ inch diameter and 4 or 5 inches in length—is taken, and one end placed in a Bunsen or blowpipe flame until the glass softens sufficiently to mass together, close up, and become solid to the extent of about $\frac{1}{8}$ inch. (See Blowpipe.) Whilst still red-hot and soft, the mouth should be applied to the open end, turning the tube round in the fingers, and meantime blowing with enough pressure to swell out the molten glass. It may be necessary, and often is so, to reheat the blown-out part and repeat the blowing until a bulb of the right size and shape is obtained.

Bulb-tubes thus prepared are useful for observing the behaviour of solid chemical substances placed in them for that purpose when heat is applied, and some illustrations are appended.

The conveyance to the bulb-tube of the substance to be examined can be easily effected by the use of a sharply channelled slip of paper.

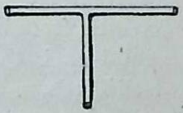
Iodine will be seen to volatilize, and give off fumes of its own colour, and to recondense to the solid state in the upper (cooler) part of the tube.

Sulphur can be seen to melt and pass through the stages described on page 103, including sublimation and recondensation.

Mercury can be sublimed and seen to condense on the upper cool part of the tube; so also ammonium chloride.

Lead filings can be melted in the bulb.

White-lead is decomposed, carbon dioxide being given off as gas, and yellow litharge being left behind in the tube.



Glass **T**-pieces, of which an illustration is shown, can be made with a little practice, and are often wanted in the laboratory. Take a piece of glass tube of the desired length, and close one end with a small boring of cork; then hold it in the flame of a blowpipe so that a fine tongue of flame impinges upon and heats the tube in one spot only, near the middle; and when it is observed to be red-hot, remove the tube from the flame and place the open end quickly in the mouth. Upon blowing, the molten part will become distended into the shape of a swelling or balloon, so thin that it can easily be broken, thus leaving a hole in the tube, the edges of which can be rounded off with a file. Next, take another piece of glass tube and blow a bulb at one end as previously described, taking care, however, in this case to blow the bulb as large, and therefore as thin, as possible. This bulb is then to be broken and the edges rounded off as in the other case with a file, when it remains to join the two pieces together. We have then the one tube with a hole in its centre, and the other tube with one end provided with a sort of lip roughly fitting the hole as to size. The flame of the blowpipe should now be applied to both these parts, and when sufficiently softened by the heat, they can be joined together (welded) in the flame.

Glass Plates of various kinds are used in laboratories: some as described under "Desiccator" and "Bell-Jar"; others, again, for covering beakers containing chemical liquids or mixtures; and other smaller ones for spreading thin layers of chemical substances for examination under the microscope, etc.

Glass Rods of various diameters and lengths are chiefly used for stirring purposes, the ends being made smooth by fusion in a Bunsen or blowpipe flame. It is useful in practice to cover the lower end with about ½ inch length of a closely fitting piece of rubber tubing, projecting just beyond the end of the rod, so as to protect thin glass vessels from breakage during stirring. Glass tubes fused solid at both ends may sometimes be used instead of solid rods.

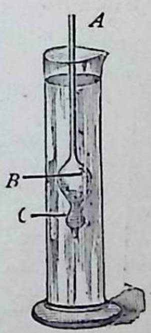
Glass Tubes are of various diameters, and can be connected together when desired by rubber tubing. The ordinary size is about 5 millimetres outside diameter. They can be bent to any desired shape by heating (meantime turning them round), until softened, in the flame of a fish-tail gas-burner, and then applying pressure by the hands until the desired bend or angle is reached. During this heating the tube becomes covered with deposited soot (due to the imperfect combustion of the carbon constituents of the gas), and it is best to leave this on the glass until it is cold, as by so doing the cooling (annealing) is prolonged and there is less liability to fracture.

To cut a glass tube, place flat on the bench, and then with the edge of a triangular file make a scratch where it is to be cut. Upon grasping the tube firmly in both hands and gentle application of pressure, it should break evenly across. When the tube is thick or the diameter greater, several file markings should be made in the same circumferential ring, or the filings should be made deeper. A glass tube can be drawn out to a smaller dimension or to a fine point when heated, as, for example, when it is desired to make the longer tube for use in a wash-bottle. When the tube so drawn out has cooled it is cut, as already described, at the drawn-out part.

The rough edges of glass tubes can be ground off with a flat file or rounded off evenly by gently softening in the edge of a Bunsen flame.

Graduated Measures.—See Measures.

Hydrometer—An appliance of a simple character very useful for determining the approximate specific gravity of liquids. It consists of a graduated glass stem, *A*, attached to a globe of glass, *B*, which is counterpoised by an adjusted weight attached to the lower end, which often takes the form of a small quantity of mercury imprisoned in a bulb, *C*. When placed in any liquid contained in a cylinder sufficiently deep, as shown in figure, it sinks until it has displaced a



volume of the liquid equal to its own weight. In a heavy liquid it will sink to a smaller extent than in a lighter liquid. They are made of several types—*i.e.*, for liquids lighter than water and for those which are heavier, but in both cases so constructed that a part of the graduated stem floats above the surface of the liquid, the density of which is to be determined. Sikes's hydrometer for ascertaining the alcoholic strength of spirituous liquors is constructed on this principle, and there are tables made out so that the graduations on the stem correspond to definite percentages of alcohol, water being marked as zero or the standard. "Proof spirit" consists of 50·76 parts water and 49·24 parts alcohol by weight, and indicates alcohol of specific gravity 0·920 at 60° F. (15·6° C.).

It is important in determining densities by means of the hydrometer to pay great attention to the temperature, as small differences in that respect make considerable variations in the result. It is usual to observe at a temperature of 15° C., at which temperature the hydrometer is graduated.

Kipp's Apparatus—See Gas Generators.

Liebig's Bulbs—See Potash Bulbs.

Liebig's Condenser—See Retort.

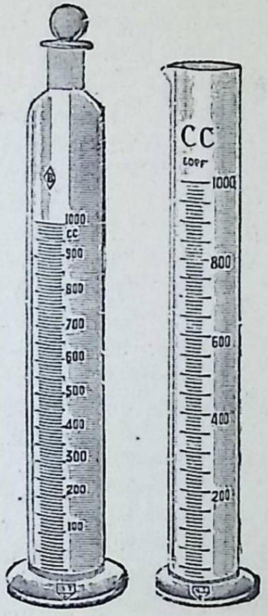
Litmus-Paper is absorbent filter or blotting paper stained by soaking (and subsequent drying) in a solution of litmus, which is an organic blue colouring matter. Acid solutions turn this blue into red, and alkaline solutions restore the blue colour, so it is very frequently used to determine the alkaline or acid nature of liquids. Litmus-paper can be prepared of a neutral tint equally amenable to both reactions. (See page 25.)

Litmus Solution may be used for the same purposes.

Magnet—See page 7, and make the experiment there described.

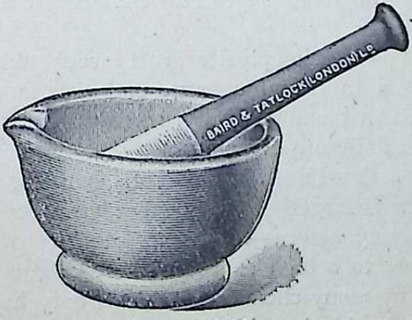
Magnet.

Measures, made of glass, are of various shapes and forms. Flasks, both stoppered and unstoppered, properly marked on their necks and holding respectively 50 c.c., 100 c.c., 200 c.c., 250 c.c., 500 c.c., and 1,000 c.c. (1 litre), are commonly employed; also cylindrical measures (as illustrated) of various sizes, graduated in cubic centimetres up to, say, 5 c.c., 10 c.c., 25 c.c., 50 c.c., 100 c.c., and so forth. . . . These latter are generally provided with a lip to facilitate the transference of the contents, as may be desired. (See also Burettes and Pipettes.)



Measures.

Mortars are grinding utensils wherewith pestles are employed to reduce minerals, crystals, and lumps of chemical substances more or less to pulverulent form (powder). They are made of various sizes and materials, including porcelain, iron, glass, and agate, and are often provided with lips to facilitate the transfer by a spatula of the contents after grinding.



Pestle and Mortar.

Percolator—See Digester.

Pestle—See Mortar.

Pinch-Cocks, as the name implies, are devices for pinching rubber tubes attached to glass apparatus, such as siphons and burettes, for the purpose of regulating the flow of liquids therefrom. This is done by the application of the fingers by way of releasing the spring which holds the clamping-wires of metal together, as shown in the one illustration. Others have screws attached to them, so that these can be adjusted to any desired extent, particularly in cases where a continued slow flow is desired, as shown in the other figure. (See Burette.)

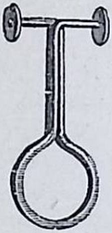


Fig. 1.

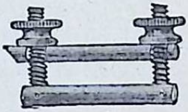
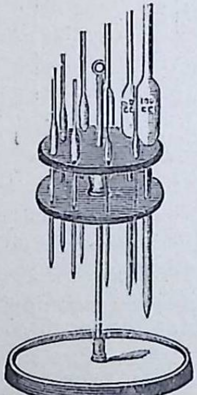


Fig. 2.

Pipettes, as held in a pipette-stand, are shown in the illustration. They are used for transferring a given measure of liquid from one vessel to another, and are made to hold definite quantities, such as 5 c.c., 10 c.c., 20 c.c., 25 c.c., 50 c.c., and 100 c.c., being graduated on the stem. In practice they are filled up somewhat above the graduated mark by dipping the lower end in the liquid and sucking up with the mouth; then rapidly placing the finger (preferably moistened) on the top of the upper end, to close same after the liquid has by release reached the marking on the stem. Other pipettes are made of glass tubing without a bulb and graduated throughout their length into c.c. and fractions of c.c.



(N.B.—In using pipettes great care should be taken to keep the lower end well immersed in the fluid to be sucked up, so as to avoid drawing the fluid into the mouth.)

Platinum in the forms of **Crucibles, Dishes, Foil, Spatulas, Weights, Wire**, etc., is largely used in laboratories on account of its refractory nature—that is, its capacity of withstanding exposure to a high degree of heat without damage and attack by many chemicals. It can only be dissolved by nitrohydrochloric acid (*aqua regia*). Care has to be taken, however, that it is not exposed to the action of other molten metals such as lead, as the two metals will form an alloy if exposed to a sufficiently high temperature, and result in the ruin of the platinum, which is a very costly metal.

In the form of foil as held by a pair of tongs in the hands, it is very useful for testing the action of heat upon chemical substances placed on its surface, the foil being placed directly over the flame of a spirit-lamp or Bunsen burner. It can thus be ascertained whether the substance fuses or chars (indicating the presence of organic matter), or is volatile, or gives off a distinctive smoke or odour; and if it burns, whether it does so with any notable feature or communicates any particular colour to the flame to which it may be exposed, and so forth.

Platinum Crucibles are most useful for exposing substances to heat with the view of burning off volatile or organic constituents, or of fusing refractory substances with added chemicals (fluxes) in order to obtain them in a form soluble in some menstruum.

Platinum Dishes are utilized for evaporation of solutions which are likely to attack glass or porcelain.

Platinum Weights of small amounts are valuable because the metal does not tarnish in the air, and the weights are not easily corroded by accidental contact with chemicals, as are copper and brass weights; 0·5 gramme, 0·2 gramme, 0·1 gramme, and some smaller ones, are among those frequently employed. (See Scales.)

Platinum Wire is useful for stirring liquids which attack glass rods, and for exposing liquids or solids spread over its surface to the flame of a Bunsen burner, in order to note the distinctive features attendant thereon. For this application the wire is bent into a loop at one end, so that a bead of the liquid or solid to be tested may be held thereon, the other end of the wire being held by tongs, or fixed in a wooden handle, or fused into a glass tube. For example, it will be found that sodium compounds make the flame yellow in colour, calcium compounds give a red colour, and so forth. The following table is by no means exhaustive, but advantage may be taken of it by beginners to make tests accordingly :

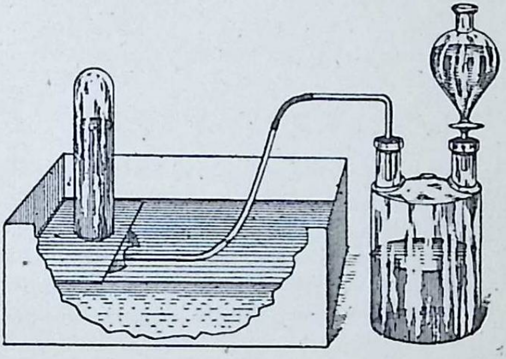
Potassium chloride gives a lilac colour to the flame.
Sodium ,, ,, yellow ,, ,,
Calcium ,, ,, brick-red ,, ,,
Barium ,, ,, green ,, ,,
Strontium ,, ,, red ,, ,,
Magnesium ,, ,, white ,, ,,
Copper ,, ,, green ,, ,,
Lithium ,, ,, brilliant crimson colour to the flame.
Lead, arsenic, and antimony compounds give a bluish-white colour to the flame.

Borax melts to a clear vitreous mass when heated, and as it exhibits the power of dissolving many metallic compounds when in this condition, it can be usefully employed for testing purposes. For example, using a looped platinum wire as above described, it can be made to take up a small quantity of borax, which can then be fused so as to make a clear bead in the loop by heating and dipping afresh in the borax whilst still hot until it is sufficiently large. If such a bead be touched with a compound of cobalt, it will, upon remelting and subsequent cooling, be found to have an azure or deep blue colour, according to the quantity of cobalt used.

Manganese compounds communicate a violet, lilac, or purple colour if the bead be heated in the outer (oxidizing) flame of a blowpipe ; but this colour is lost if the bead be heated in the inner (reducing) flame, owing to chemical changes that occur under these different circumstances.

Chromium, iron, copper, and other salts, may be examined by the student using both flames of the blowpipe.

Pneumatic Trough—An appliance used for the collection of gases over water, consisting of a trough made of tin-plate, stoneware, or glass, and provided with a shelf as shown in figure. In use it is charged with water, so as to well cover the shelf near the top. To illustrate its actual employment the following experiments may be made: Take 2 or 3 grammes of potassium chlorate crystals, add a little manganese dioxide—which facilitates by catalytic action (see page 117) the evolution of oxygen from the chlorate (see page 56)—and place the mixture in a test-tube fitted with a cork and bent tube, and secured in a holder on a suitable stand. The end of the bent tube is passed into the water in the trough and up underneath a test-tube or small bottle filled with water and inverted and placed over the funnelled hole in the shelf. Upon heating the mixture in the test-tube, oxygen gas will be liberated, and as generated it will pass along the tube, bubble up, and displace the water in the bottle. When the bottle is nearly filled with oxygen, the stopper may be inserted under the surface of the water, and then removed from the trough. (See also Flasks.)



(N.B.—Do not take away the lamp from under the test-tube before removing the tube conveying the gas, from the trough.)

The illustration shows the employment of the pneumatic trough for collecting oxygen gas as produced by a different process and apparatus. This employs a Woulfe's bottle fitted with a stoppered separating-funnel which is to be charged with a saturated solution of potassium permanganate, whilst the bottle itself is half filled with a solution of hydrogen dioxide strongly acidulated with dilute sulphuric acid. Upon opening the stopper in the funnel and thus allowing the permanganate to drop gradually into the contents of the bottle below, oxygen gas will be produced by the interaction shown in the equation set out below, and will pass by way of the bent tube into any vessel filled with water and inverted over the shelf of the trough.

$$2KMnO_4 + 5H_2O_2 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 8H_2O + 5O_2.$$

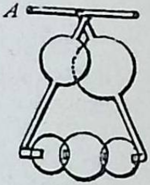
That is to say, half the oxygen comes from the permanganate and half from the hydrogen dioxide which is reduced to water, the potassium and manganese sulphates which are formed at the same time remaining in solution. If a sufficient excess of acidulated hydrogen dioxide be employed, the colour of the permanganate dioxide solution is wholly destroyed.

Several observations may be made with oxygen gas collected as described. By placing a test-tube filled with water in a vertical position in the trough under the water surface, a little of the oxygen can be transferred to it from the bottle or tube containing it, when also vertically inverted under the surface of the water, by tilting it so that the gas will bubble up from the lip of the one vessel into the other one. Close the mouth of one such test-tube with a finger of the left hand and remove it from the bath, and having lighted a match or wooden spill with the right hand and blown it out so as to leave a spark glowing at the end, it will be found, on placing the glowing end in the test-tube, that it will burst into flame. (See page 54.) Other experiments may be made with oxygen gas as described under the heading of Deflagrating-Spoon.

Hydrogen, and any other gas that is not soluble in water, may be collected over water in a pneumatic trough.

Chlorine gas cannot be collected in that way, as it is soluble in water.

Potash Bulbs—This appliance is largely employed in the practical analysis of organic substances, being charged with a solution of caustic potash of specific gravity 1·26 for the purpose of absorbing the carbon dioxide gas generated in course of combustion. It consists of five glass bulbs blown out of a piece of tube as shown in the figure, so that gas entering at *A* is successively washed three times as it bubbles through the three bulbs shown at the base. The bulbs being weighed before and after the operation, gives by the increase in weight, an exact determination of the carbon dioxide absorbed as generated in the process forming the subject of investigation. Potash bulbs can also be used for washing other gases in various liquids. (See Combustion Tube.)



Reagents are solutions of various chemicals used for testing purposes, comprising strong hydrochloric, nitric, and sulphuric acids; dilute solutions of the same acids of strength 1 part to 4 parts water; and various salts containing about 5 per cent. of the respective substances—that is to say, 5 grammes by weight per 100 c.c. dissolved in water. These should be placed in 6 or 8 ounce glass-stoppered bottles and arranged on a shelf running along the back of the working bench, or at the back of the bench itself. Each bottle should be labelled with the full name and the chemical formula of the reagent.

Great care should be taken in handling the strong acids and the strong alkalies, as they are very corrosive to the skin and destructive of clothing.

The following experiments making use of reagents may all be made in test-tubes (see Test-Tubes):

(A) Place about 5 c.c. of litmus solution by means of a pipette in a test-tube, and add a drop of either of the dilute acids above named, and the litmus solution will then turn red in colour; next, add 1 or 2 drops of either of the alkaline hydrates, and the solution will now be changed back to blue again. (See page 25.)

(B) To 5 c.c. sodium carbonate solution (Na_2CO_3) add, drop by drop, dilute hydrochloric acid (HCl) and note the effervescence caused by generation of carbon dioxide (CO_2)—

$$Na_2CO_3 + 2HCl = 2NaCl + H_2O + CO_2.$$

This gas will be found to extinguish the flame of a lighted spill inserted in the tube in which it is generated.

(C) To 5 c.c. lead acetate ($Pb(C_2H_3O_2)_2$) add some few drops of dilute sulphuric acid (H_2SO_4) and note the precipitation, in finely divided form, of white lead sulphate ($PbSO_4$), which is insoluble in water:

$$Pb(C_2H_3O_2)_2 + H_2SO_4 = PbSO_4 + 2C_2H_4O_2$$

the acetic acid remaining in solution.

(D) Place 5 c.c. dilute ammonium hydrate (NH_4HO) in a test-tube, add some few drops litmus solution, and after taking note of its smell, add carefully, drop by drop, dilute nitric acid (HNO_3) to it and observe that the mixture becomes warm, and after it has become neutralized, as shown by the change of colour, the smell of free ammonia will have disappeared—

$$NH_4HO + HNO_3 = NH_4NO_3 + H_2O,$$

the ammonium nitrate which is produced in solution being practically odourless.

(E) Add potassium iodide (KI) solution to one of lead acetate ($Pb(C_2H_3O_2)_2$), and note that a beautiful canary-yellow precipitate of lead iodide (PbI_2) is produced—

$$Pb(C_2H_3O_2)_2 + 2KI = PbI_2 + 2K(C_2H_3O_2),$$

the potassium acetate which is also produced remaining in solution.

(F) Add ammonium sulphydrate (NH_4HS) to lead acetate ($Pb(C_2H_3O_2)_2$), and note the heavy precipitate of black lead sulphide (PbS) produced by the interaction—

$$Pb(C_2H_3O_2)_2 + NH_4HS = PbS + NH_4H(C_2H_3O_2)_2.$$

(G) Replacing the NH_4HS in the last-described experiment by potassium chromate (K_2CrO_4), note the production of yellow precipitated lead chromate ($PbCrO_4$) (see page 88)—

$$Pb(C_2H_3O_2)_2 + K_2CrO_4 = PbCrO_4 + 2K(C_2H_3O_2),$$

the potassium acetate remaining in solution.

(H) To a small quantity of silver nitrate ($AgNO_3$) solution add dilute hydrochloric acid (HCl), and observe the formation of a white curdy precipitate of silver chloride ($AgCl$)—

$$AgNO_3 + HCl = AgCl + HNO_3,$$

the nitric acid passing into solution. Allow the mixture to settle, and then, after carefully pouring off the clear liquid (leaving the white precipitate at the bottom of the test-tube), add dilute ammonium hydrate (NH_4HO), when it will be observed that, upon shaking, the silver chloride will be dissolved by the ammonium hydrate in which it is soluble.

On addition of a sufficient quantity of dilute nitric acid (HNO_3) it will be reprecipitated, the nitric acid combining with the alkali to form ammonium nitrate, and thus throwing the AgCl out of solution, with evolution of heat.

(I) Sodium carbonate (Na_2CO_3) added to calcium chloride ($CaCl_2$) will produce a white precipitate of calcium carbonate—

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

When a fair amount of the precipitate has been obtained, allow it to settle in the test-tube, then pour off (decant) the clear liquid above (supernatant liquid), and add to the thick mixture left behind, a small quantity of dilute HCl, when the following interaction will be witnessed :

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2,$$

the carbon dioxide being given off in gaseous form.

(J) Place some clear lime-water in a test-tube, and by means of a short length of glass tubing, blow air from the mouth through the liquid for some few minutes. The carbon dioxide contained in the breath (respired air) will be seen to produce a precipitate of $CaCO_3$, which can be dissolved again by the addition of hydrochloric acid.

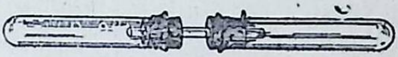
(K) Place some few iron filings in a test-tube, add about 10 c.c. of dilute hydrochloric acid (HCl), and by means of a test-tube-holder warm the contents in the flame of a Bunsen burner. It will be observed that the metal will gradually pass into solution, forming ferrous chloride, with evolution of hydrogen gas. Without waiting for all the metal to be dissolved, the liquid may be decanted into another test-tube, and now, by the addition of any of the alkaline solutions, there will be obtained a greenish-grey precipitate of the ferrous hydroxide, ($Fe(HO)_2$) or FeH_2O_2.

(L) Similar experiments may be made with copper filings and zinc shavings, obtaining thereby precipitates of the hydroxides of copper and zinc, ($Cu(HO)_2$) and $Zn(HO)_2$ respectively.

(M) Take a dilute solution of copper sulphate, and then place in the solution some iron filings or metallic zinc, and observe the replacement of the copper in solution (which gradually loses its blue colour) by the iron or zinc, and the deposition of the copper thrown out. (See page 18.)

(N) Make similar experiments, using (1) a dilute solution of mercuric chloride ($HgCl_2$) and copper turnings (see page 19), and (2) a dilute solution of silver nitrate and copper turnings.

(O) Take two test-tubes of the same size, and fit each with a cork ; then bore a hole through each cork and run a short length of glass tubing through the two borings so as to connect them together. Next, place 2 or 3 drops of strong hydrochloric acid in one test-tube and 2 or 3 drops of strong ammonium hydrate in the other, and turn the tubes round and round so as to spread the contents well over their inside surfaces; then, after draining the tubes, fit the corks into them as shown in figure. Upon placing



the tubes in a vertical position, the ammonia tube being held below in the warm hand, it will be noted that the fumes of the ammonia will gradually pass (diffuse) into the other tube (see page 6), and a white cloud of ammonium chloride will be produced and gradually deposited on the end of the connecting-tube—

$$HCl + NH_4HO = NH_4Cl + H_2O.$$

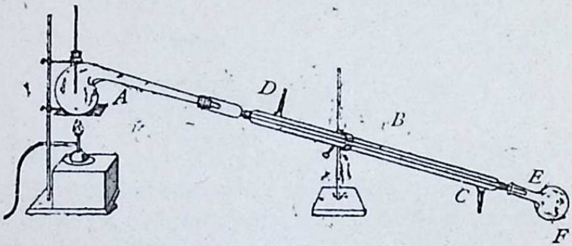
(P) Dissolve a small quantity of ammonium chloride in a minimum quantity of water in a test-tube, add a little sodium hydroxide solution, and warm the mixture, observing the odour of the liberated ammonia vapour, and its alkaline behaviour to litmus-paper—

$$2NH_4Cl + 2NaHO = 2NaCl + 2NH_3 + 2H_2O.$$

(Q) A dry mixture of lime and ammonium chloride, when heated in a test-tube, also furnishes a supply of ammonium gas by the interaction—

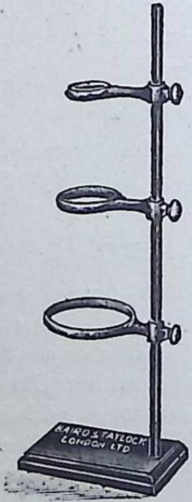
$$2NH_4Cl + CaH_2O_2 = CaCl_2 + 2NH_3 + 2H_2O.$$

Retort or Still—The illustration given below shows an apparatus employed for distilling purposes, consisting of the body *A* (in which the liquid to be distilled is introduced through the tubulure, which can be closed with a glass stopper or cork) with shoulder and tube through which the vaporized substance passes to the condenser. The retort is held in position by a retort-stand (see figure), the body resting upon a sheet of wire gauze placed on one ring of the stand, while the neck of the retort can be secured or held in position by a smaller ring of the same stand. The heat is applied by a lamp placed below the retort. The student may distil a small quantity of water, with or without the use of the Liebig's condenser by way of experiment.



This figure shows a thermometer passing through the cork fitting the tubulure of the retort.

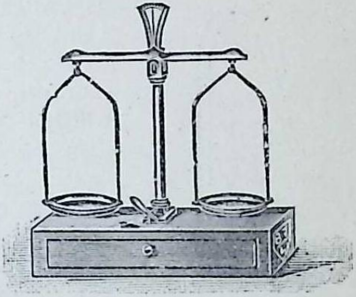
Liebig's condenser (*B*) is a simple appliance for assisting, by cooling, in the condensation of vapours carried over from retorts, and consists of a water-jacket (surrounding a tube which has to be connected with the retort) through which a stream of cold water is made to pass, entering by the attached tube, *C*, at the lower end, the warmer water thus replaced passing out of the condenser through the upper attached tube, *D*. The vapour passing away from the retort through the neck is thus cooled and condensed to the liquid state, and flows out at *E* into any receiver, *F*, that may be placed there. Gas retorts for roasting coal in the process of coal-gas making are constructed on the same principle as laboratory retorts.

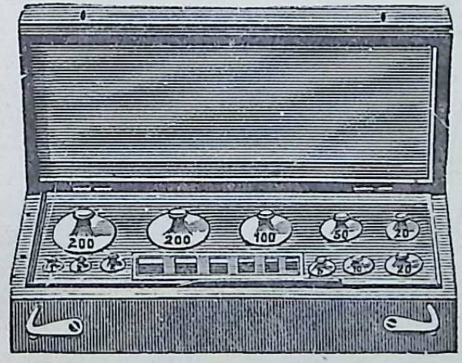


Retort Stand — A further illustration is shown at side.

Sand-Bath—See Tripod Stand.

Scales and Weights—Scales or balances are made in great variety, some for heavy weights, others more particularly for light weights, and some of the utmost delicacy, having pans turning with one-tenth of a milligramme (0·0001 gramme), the knife edges and bearings being of agate. For beginners, however, a balance of great delicacy is not required, and a very good one is shown in the figure, which carries up to 100 grammes and is sensitive to 5 milligrammes. A useful set of weights in a box or case consists of a series from 0·01 gramme up to 50 grammes, the smaller ones being made of aluminium and the larger ones of brass (see figure).





The article to be weighed is placed in the left-hand pan and the weights in the right-hand pan, the pans being raised from the platform by means of the short lever handle shown in front. The weight of the article is that of the added weights in the right-hand pan when the two pans balance evenly.

Separating-Funnel—See Digester.

Separator—See Digester.

Siphon—An appliance for drawing off (siphoning) fluids from one vessel to another. Suppose, for instance, we have a beaker of fluid containing a precipitate of barium sulphate at the bottom, and it is desired to draw off the supernatant fluid without disturbing the precipitate, a siphon may be employed for the purpose. It consists of a bent tube, as shown in the one figure, one limb of which is preferably somewhat longer than the other. Upon filling it with water, closing the end of the longer arm with the finger, inverting the tube and placing the short end in the liquid to be decanted, it will commence to flow from the beaker directly the finger is removed from the end of the longer branch, and may be disposed of as desired. If collected in another vessel, the liquid will continue to flow over until the level of the collected liquid is the same as that in the vessel from which it flows, but by lowering it the liquid may all be drawn off—that is to say, so long as the vertical column is longer on one side than on the other—the flow being dependent upon atmospheric pressure. The siphon illustrated in the second figure is fitted with a suction-tube to start the flow by drawing the fluid up the one tube, *A*, and down into the other, *B*, by means of the mouth applied at *C*.

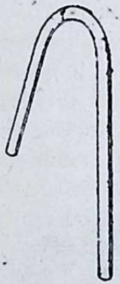


Fig. 1.

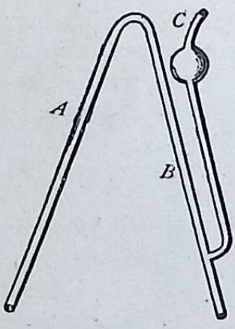


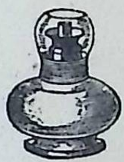
Fig. 2.

Spatula—A flat, broad blade used for transferring solid or pasty substances from one container to another. Spatulas are made of various materials, according to the nature of the substance

to be manipulated—some of iron or steel, fixed in a wooden handle, as shown above, and others of ivory, platinum, nickel, aluminium, etc.

Specific-Gravity Flask—This is used for determining the specific gravity of fluids by weight, and in practice it is usual to employ a stoppered flask filled at 15·5° C., the stopper being inserted so that the liquid overflows and no air is left in the flask. Its weight (after drying it externally) as compared with that of water determines the specific gravity. The weight of the liquid (after deducting that of the empty dry flask) having been ascertained, and that of the same quantity of water at the same temperature being known, the specific gravity of the liquid is ascertained by dividing it by the latter. (See also Hydrometer.)

Spirit-Lamp—An appliance, generally made of glass, consisting of a container in which is placed methylated spirit and a cotton wick which dips into the alcohol and passes through the neck, being held in its position by a disc of metal or porcelain lodging or screwed thereon. It is very useful for gentle heating purposes.



Spirit-Lamp with Cap.

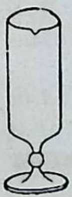
Still—See Retort.

Stoppers are made of cork, glass, rubber, wood, or other composition, according to the nature of the contents of vessels to be sealed.

Strainers—See Filters.

Sulphuric-Acid Tube—See Drying-Tube.

Test-Glasses are of several varieties, the common form consisting, as shown in figure, of a body open at the top and supported by a stem and stand. They are useful for making mixtures of larger quantities than can be accommodated in test-tubes, and which can be easily stirred by means of glass rods.



A test-glass may be used to illustrate the decolorizing property of charcoal by taking a very dilute solution of magenta or other organic colouring matter and shaking and stirring a mixture of it with a quantity of animal charcoal. Upon filtering the mixture after a time, the liquid will be found to be colourless.

A test-glass may also be used for the following experiment: Place about 20 c.c. of potassium iodide in the glass, and gradually add a dilute solution of mercuric chloride ($HgCl_2$), when a beautiful scarlet precipitate of mercuric iodide (HgI_2) will be produced. It will be found that this precipitate is soluble in an excess of either mercuric chloride or potassium iodide.

Test-Tubes are thin glass tubes of special quality and various diameters ranging from about $\frac{1}{4}$ inch to 1 inch, sealed at the lower end and sometimes provided with a lip at the upper end. (Illustrations of them will be found under the headings of Kipp's Apparatus and Reagents.) They are chiefly employed, as implied by their name, for making chemical tests. (See Reagents.) They are capable, when containing liquids, of withstanding the direct application of flame, such as that of a Bunsen burner. The following experiments may be made, using test-tubes:

(1) Make a mixture of about $2\frac{1}{2}$ grammes of sulphur and $3\frac{1}{2}$ grammes of iron filings, place it in a test-tube, and, holding the test-tube in a clamp (or by means of a doubly folded strip of blotting-paper held round the neck of the tube by the hand so as to secure it), warm gently over the flame of a spirit-lamp or Bunsen flame. When the mixture begins to glow, as it will do, remove from the flame, and note that the glow due to chemical combination continues for some time, resulting in the production of iron sulphide. When quite cold, add a little dilute hydrochloric acid, and note the evolution of hydrogen disulphide—

$$FeS + 2HCl = FeCl_2 + H_2S.$$

(2) Place two or three small crystals of copper sulphate in a test-tube and heat gently over a flame, taking note of the separation of water and the change of colour that takes place owing to this loss of water of crystallization.

After cooling, add a drop or two of water, and note the restoration of colour by the re-formation of the original combination attended by an evolution of heat. Copper sulphate ($CuSO_4 5H_2O$), heated to 100° C., loses $4H_2O$, and at 200° C. it loses the whole of the $5H_2O$.

(3) Place about 5 c.c. of a dilute solution of iodine dissolved in potassium iodide in a test-tube, and, after adding 5 c.c. of turpentine or chloroform, well shake the mixture and observe the decolorization of the watery part of the mixture by reason of the greater solubility of the iodine in the turpentine or chloroform.

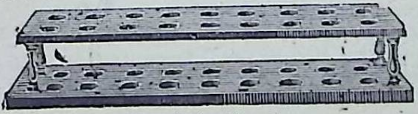
(4) Place some few drops of dilute ammonium sulphydrate in a test-tube, then gradually add hydrogen dioxide, well shake, and note the disappearance of the characteristic odour of the sulphydrate and the milkiness which ensues due to the separation of sulphur, as expressed by the equation—

$$NH_4HS + H_2O_2 = NH_4HO + H_2O + S.$$

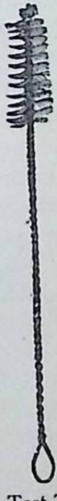
Test-Tube Brushes are constructed of bristles attached laterally and to the bottom of wire supports with handles, and are designed to clean out test-tubes after use (in course of washing) by brushing their sides and bottoms. They are made of various sizes to suit the several sizes of test-tubes.

Test-Tube Holder—A simple contrivance in the nature of a hand-clamp to hold a test-tube when it is required to heat or boil the contents by the flame of a lamp. (See also Clamps.)

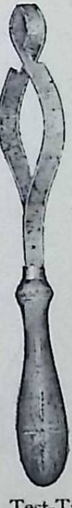
Test-Tube Stands are simple wooden



Test-Tube Stand.



Test-Tube Brush.



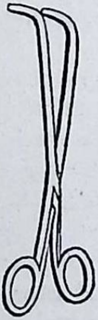
Test-Tube Holder.

appliances made to hold test-tubes in a vertical position, as shown in figure.

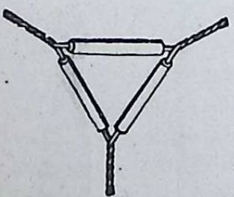
Thermometer—See page 41.

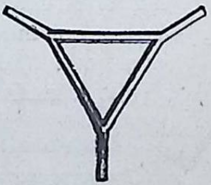
Thistle-Funnel—A small funnel-head with tube by means of which a liquid can be conveyed into any vessel with which it may be connected. (See Drying-Tube.)

Tongs—There are several varieties of tongs and crucible tongs, and a form in ordinary use is shown in figure. They are generally made of iron, some with pointed ends, and others with flattened ends made or faced with platinum (so that no metallic contamination may take place in respect of any chemical substances with which these protected ends may come into contact). They are most useful for holding foil, or crucibles, or small dishes, and for removing them whilst hot from one situation to another. In some cases the handles are covered with string or other non-conducting material, so as to avoid the inconvenience otherwise experienced by the conduct of heat to the hands. Other tongs, more in the character of forceps, as shown in figure, are made of brass, with pointed ends, and are employed for the transference of weights from their boxes to the pans of scales or balances in weighing operations, etc.



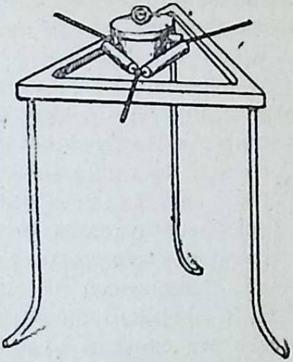
Triangles—Wire run through the hollow stems of pipe-clay, broken up into short lengths, finds use in the shape of triangles for supporting crucibles or funnels (in filtering operations); and being capable of withstanding high temperatures, are often used when the crucibles or dishes held thereon have to be strongly heated in gas flames, etc. Other triangles are made of plain iron, as shown in the other figure.





Tripod Stand—This is an iron stand consisting of a ring or tripod of iron supported upon three legs, as shown, although in point of fact stands of larger size are often provided with four legs, thus securing a better balance.

These stands are employed for many purposes, but always to support other vessels. In use the top of the stand is often covered with a piece of wire gauze on which the vessel (flask, beaker, dish, or water-bottle) is placed, and can thus be heated by means of a lamp placed below. In other cases, the wire gauze is replaced by an iron saucer containing a thin layer of sand used for the same purpose and known as a "sand-bath." Retorts can be placed on the wire gauze or sand-bath for the purpose of effecting distillation, the retorts being held by the neck by means of rings or clamps attached to stands. (See Retorts; also Triangles.)

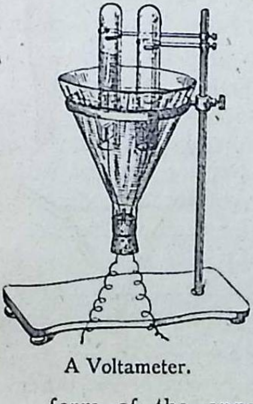


Tripod and Triangle supporting a Crucible.

Turmeric Paper is coloured with the yellow colouring matter called "turmeric," which is turned brown by alkaline solutions. It is sometimes used instead of red litmus-paper. (See Litmus-Paper.)

U-Tubes—See Drying-Tubes.

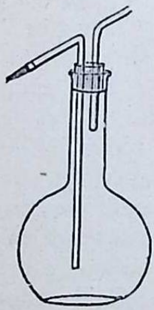
Voltameter—An appliance for the electrolysis of water—that is, its decomposition by means of an electric current. (See page 48.) A simple form of the apparatus (as illustrated) consists of an



A Voltameter.

inverted funnel-head, the neck of which is closed with a cork or composition through which are passed two platinum wires terminating above in small plates of the same metal. The funnel is partly filled with water, and over the upright platinum plates are inverted two test-tubes filled with water acidulated with a little sulphuric acid (to assist the passage or conductivity of the electric current). On connecting the wires with a battery of three or four cells the current passes, and by decomposition of the water causes the production of 2 volumes (parts) of hydrogen gas in the one tube and 1 volume (part) of oxygen gas in the other. (See page 20; see also Eudiometer.)

Wash-Bottle—This consists of a flask fitted with a cork or rubber stopper with two borings, through which pass two bent tubes: a short one terminating just below the stopper, while the other goes nearly to the bottom of the flask and terminates at the outside end in a drawn-out point, so that when in use, as, for instance, washing a precipitate upon a filter, the water emerges therefrom in a fine stream.



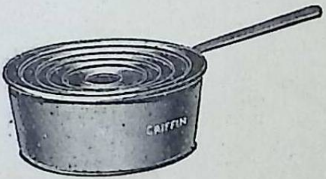
By applying the mouth to the short tube and blowing, the water is forced out of the flask through the longer tube. The water can be hot or cold, as desired. This apparatus is most commonly used for washing precipitates on filters free from associated soluble substances. In other cases, wash-bottles, instead of being filled with water, are charged with alcohol, ether, or other solvent, according to the solubilities of the substances to be removed from the subject-matter of the washing.

Appliances similarly constructed, using either flasks or bottles, are also used for washing gases, the gas being passed or drawn through the liquid contents by the long tube, and the washed gas escaping through the shorter tube. (See Woulfe's Bottle and Aspirator.)

Watch-Glasses are sometimes used for making chemical tests with small quantities of reagents and stirring with a glass rod, also for holding (containing) small quantities of dry chemical substances, in which case two of them (having ground edges) are held together with a brass clamp. (See Clamps.) They are also used to test the volatility of liquids—for example, if small quantities of alcohol, ether, and turpentine be placed on watch-glasses and then exposed to the air for some time, the liquids will be volatilized without leaving any residue. The volatilization takes place, of course, more quickly if they are placed on a warm sand-bath or on the top of a hot water-oven.

(N.B.—Don't allow the vapours of these liquids to come into contact with flame, as they are inflammable.)

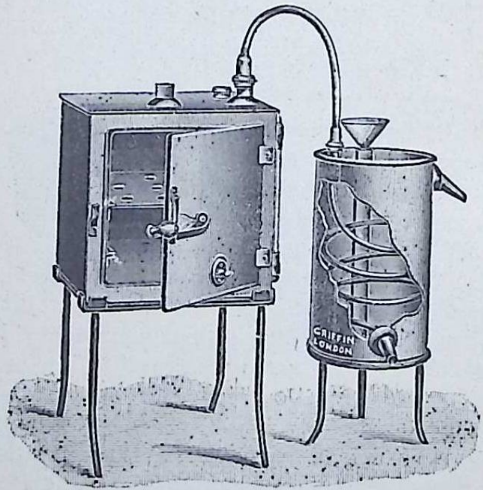
Water-Bath—A sort of saucepan, and saucepans are, in point of fact, sometimes used. A properly constructed water-bath is fitted on the top with a flange, upon which may be placed movable, thin, flat discs of metal, so as to accommodate the evaporating-basin or other vessel according to its size. The applications made of this contrivance are various, the chief use being in connection with the concentration or strengthening of liquids contained in evaporating-dishes, which are placed on the discs on top of the bath, which itself is charged with water up to about two-thirds of its capacity. In this way, by boiling the water in the bath (using an appropriate gas-lamp for that purpose), the evaporation of the liquid to be concentrated is carried out to the desired extent. Sometimes this is done with the mere view of concentration; at others, with the object of concentrating the solution to such an extent that, upon cooling, the substance may separate out in a crystalline condition; whilst in yet other cases, as, for example, when mixtures of substances are in solution, the purpose is to



separate out, more or less, the least soluble constituent, which in that case will often be precipitated in a solid form out of solution upon cooling.

Again, water-baths are often employed for merely heating chemical liquids or mixtures contained in beakers or flasks, placed actually in the body of the water (resting upon a piece of rag or cloth at the bottom) and secured against upsetting by the movement of the boiling water by means of the discs of metal placed around them on the top of the saucepan or water-bath. This application is generally spoken of as digestion at 100° C.

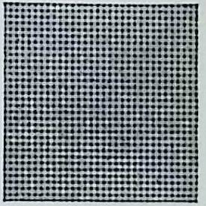
Water-Oven—An appliance, as illustrated in the figure, in which it is possible to dry chemical substances (in suitable containers) at 100° C., consisting of a water-jacketed copper box which can be heated by a lamp placed below. A vent is provided for the escaping steam and for charging the jacket with water, and through the other open tube on the top a thermometer fitted with a cork may be placed. The figure shows such an oven connected with a condenser for the escaping steam, which may be thus made to furnish a supply of distilled water.



Weights—See Scales.

Winchester Bottles are made of pale or dark blue or amber glass. Full-sized Winchesters hold about 80 ounces or, roughly, about 2 litres, and smaller ones 40 and 20 ounces respectively. They are useful for holding large supplies of various chemical solutions, the dark blue and amber ones being specially selected for use in cases in which the liquid contents are liable to suffer decomposition by exposure to light.

Wire Gauze, both plain and asbestos-covered, in sheets of various sizes, is used on tripod stands as a support for retorts or other glass vessels which require to be heated by lamps placed below. (See Retorts; also Asbestos.)



Sheet of Wire Gauze.

Woulfe's Bottles are made with two or three necks, one of which may be provided with a stopper. For an illustration see Drying-Tubes.

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